ENERGY CONSERVATION PLAN FOR DELHI

Progress report - II

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Prepared by

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Chapter 1

Introduction

1.1 Urbanization in India: An overview

The trend of urbanization in India has been accelerating specially in the last four decades Less than 60 million at the time of independence, the urban population had swelled to nearly 217 million in 1991[1] spread over 3768 urban agglomerations/towns. The 1991 census shows that about 26 percent of the country's population is urban. The urban population in India has been growing at a much higher rate than the total and the rural population Also, the rate of growth of population has steadily risen from decade to decade except during 1981-91 (the decennial growth rate was 36 2 percent) when it was lower than the earlier decade (46 1 percent). With one in every four persons living in urban areas[1] It is expected that by the year 2001, India's population will near the 1 billion mark and nearly one-third of this population will be in urban areas.

An analysis of urban growth shows that natural increase contributed about two-fifths, net immigration another two-fifths and reclassification (new towns and area changes) about one-fifth to the urban population growth between 1981 and 1991.

There is a skewness of distribution of population among different urban agglomerations/towns with a high concentration of the urban population in a few large cities. Urban growth has mainly occurred in the 'over-one-lakh' cities (i.e Class I cities). Such a trend in Class I cities gives continuity to the pattern of urbanization which has been going in India since 1901. Over 65 percent of India's urban population lives in cities. While the growth in number of towns (each with population size less than one lakh) has not kept pace with growth in urban population, share of class II and III towns i.e. each with population size between 20,000 and 100,000) in total population has remained more or less steady Share of Class IV and smaller size towns (i.e. each with population size less than 20,000) show a steady decline.

Urban agglomerations/cities each with population size over one million, come under metropolitan area. According to 1991 census, there area twenty three metropolitan cities in the country, accounting for roughly one-third of urban population and one-twelfth of total population. There are only four mega cities - Greater Bombay, Calcutta, Delhi and Madras - each having a population of over five million, as per 1991 census results. Almost, one-fourth of the population living in Class I cities in the country lives in the giant metropolises

Slums and *Jhopar basties* have become synonymous with urbanization and all major metropolitan cities in India have large sections of population residing in inhumane and sub-standard conditions. The estimate of population of urban people living in slums in India varies from about 20 to 30 percent. Looked at by class of town, the highest percentage of people living in slum areas is in the cities, with a million plus population, and the least in towns with less than 1 lakh population.

About 27 percent of the urban population lives below the poverty line while 30-40 percent of the total population of the larger metropolitan areas lives in slums. Around 27 percent does not have access to safe water and over 75 percent does not have access to water-borne sanitation. Indian cities also have very high levels of air

and water pollution. The report of the National Commission on Urbanization[2] reveals that "for whatever reasons, resource allocation in the urban field seems to follow a problem rater than anticipate it".

1.2 Urbanization and energy

The rapid pace of urbanization and the diverse urban growth pattern are major characteristic of economic development. This involves many structural changes throughout the economy that have important implications for energy use, which becomes clear when we view the energy challenge on the basis of future projections. Urbanization brings with it changes in the ways resources are collected, distributed and used. As the cities grow rapidly, there is increasing pressure on these networks, and in many cases concern about whether they will be able to cope with the growing demand. Understanding the nature of the urban resource consumption, and in particular, the changes that take place as country's population become more urban, is an important element in planning urban supply networks that will be able to accommodate future demands.

The major implications of rapid pace of urbanization on the energy sector are.

- shift from traditional energy sources to modern fuels;
- increase in energy use on account of demand for new services in households, such as electric lighting; cooking with LPG, kerosene or electricity; electricity for refrigeration, entertainment and space conditioning devices etc;
- greater dependence on monetized formal supply networks to meet the growing energy demand;
- present urban energy system is inequitable, causing undue hardship to the urban poor;
- increased requirements for personal transportation on account of separation of place of work from residence;
- greater dependence on oil based motorized forms of transport;
- increased incomes and better living styles leading to larger energy use per capita;
- increased requirements of commercial fuel for industrial and services and commercial activities.

The energy using activities in cities can be broadly classified into the following categories:

- domestic activities - cooking, lighting, space heating/cooling, water heating
- transportation - passenger and goods movement
- commercial activities - lighting, space heating/cooling
- industrial activities - motive power, process heat, etc
- Provision of infrastructural activities - water supply, street lighting, sewerage, etc.

1.3 Need for energy conservation plan in urban areas

The fundamental problem is that the urban areas need more energy for sustainable socio-economic development and they lack resources to expand their supply system fast enough to keep pace with the growing demand. The planning mechanism so far has emphasized on augmenting energy supplies But, energy conservation has emerged as a least cost option and a practical alternative for bridging the growing demand and supply gap in energy planning.

It has been realized now that energy efficiency is an intangible resource by itself that completes economically with other energy supply options. In addition to this, major national priorities such as economic competitiveness, optimal utilization of scarce resource for development, environmental quality and energy security through oil independence provide an urgent rationale for conserving energy. Energy conservation offers a practical means of achieving these goals. It enhances the competitiveness of industry by reducing the cost of production and optimizes use of capital resource by directing lesser amounts in conservation investments as against capital intensive energy supply options. It protects the environment in the short run by reducing pollution and in the long run by reducing the scope of global climatic change. It strengthens national security at a time when domestic oil production has begun to level off and dependence on oil imports is increasing. No energy supply options can provide all these benefits. Further, energy conservation does not mean curtailment in energy use at the expense of industrial and economic growth. It also does not mean sacrifice or belt tightening, rather it means efficient utilization of energy resources ensuring the same level of economic and industrial activity with lesser inputs of energy. Energy conservation also implies the substitution of costly imported energy by cheaper and more plentiful indigenous sources of energy resources to supplement conventional sources.

In urban areas, management decisions for energy conservation are mostly decentralized unlike decisions on energy supply which are typically centralized, as they are ultimately taken by the individual consumer. The success of energy conservation programmes in urban areas depend upon their effectiveness in influencing, motivating or compelling the ultimate user to decide, adopt and implement energy conservation measures. Energy conservation calls for a collective and integrated approach in order to achieve the desired results.

Given this background and realizing the energy conservation potential of various sectors in the giant metropolises, a collaborative research study involving the Delhi Energy Development Agency (DEDA) and the Tata Energy Research Institute, New Delhi was undertaken to prepare a integrated sector-wise energy conservation plan for the capital city Delhi or the National Capital Territory of Delhi. The role of the nodal agency such as the DEDA becomes more meaningful and needs to be given due consideration in the formulation of the policies, programmes and institutional mechanisms for achieving energy conservation in energy sphere of urban development and in the planning process in Delhi.

1.4 Growth of Delhi city

1.4.1 Demography

Delhi has witnessed a phenomenal population growth during past few decades. From a population of 0.4 million in 1901, its population has grown to 9.4 million in 1991. Since 1951, the population of Delhi has been increasing at a rate of 52-53 percent every decade. During 1981-91, its population grew by 3.2 million. Taking this figure, on an average, everyday 877 persons were added to Delhi's population during 1981-91 decade. If this growth rate continues during 1991-2001, then Delhi would have 14.1 million people by the year 2001.

Urban population constitutes a major portion of total population in the National Capital Territory of Delhi. In 1981, the share of urban population was 92.73 percent in 1991. The annual growth rate of urban population of Delhi was

5.82 percent during 1971-81, while during 1981-91, the corresponding growth rate declined to 4.69 percent. The population density for urban Delhi was 14,313 persons in 1991.

Figure 1.1 shows the map of National Capital Territory of Delhi[3]. Upto 1971, only Delhi Municipal Corporation (DMC) - urban, New Delhi Municipal Committee (NDMC) and Delhi Cantonment Board constituted urban Delhi. In 1981, 27 new census towns were added which increased the area to 591.85 sq.km. in 1981 from an area of 446.26 sq.km. in 1971. The population of DMC (urban) has doubled between 1971 and 1991. As against this in the NDMC area, the population in 1981 and 1991 was less than that in 1971. The population of the Delhi Cantonment Board is less than that of NDMC. Both NDMC and Cantonment Board have about 43 sq.km. of area, but the population of cantonment is only one-third of NDMC's population in 1991. The population density has increased considerably in DMC (urban) over the last two decades, recording a density of 19,899 persons per sq.km. in 1991 as compared to 9119 persons per sq.km. in 1971.

To control the rapid growth of population in the National Capital Territory of Delhi, the National Capital Region (NCR) was formed in 1986 with the idea of diverting the population and economic activities to satellite towns. The NCR spread over 30,242 sq km. covers parts of the states of Haryana, U.P. and Rajasthan and the Union Territory of Delhi.

For the purpose of planning, the Delhi Metropolitan Area (DMA) was formed, comprising of National Capital Territory of Delhi, Ghaziabad - Loni complex and Noida in U P., Faridabad - Ballabhgarh Complex, Gurgaon, Bahadurgarh and Kundli in Haryana. The DMA which is spread over an area of 3182 sq km. is expected to contain the population of National Capital Territory of Delhi to 11.2 million by the year 2001[4] (Table 1.1).

Table 1.1 Population assignment for 2001

(in lakhs)

Area	Population assigned - 2001		
	Urban	Rural	Total
National Capital Region	234	91	325
Delhi Metropolitan Area	147	3	150
National Capital Territory of Delhi	110	2	112

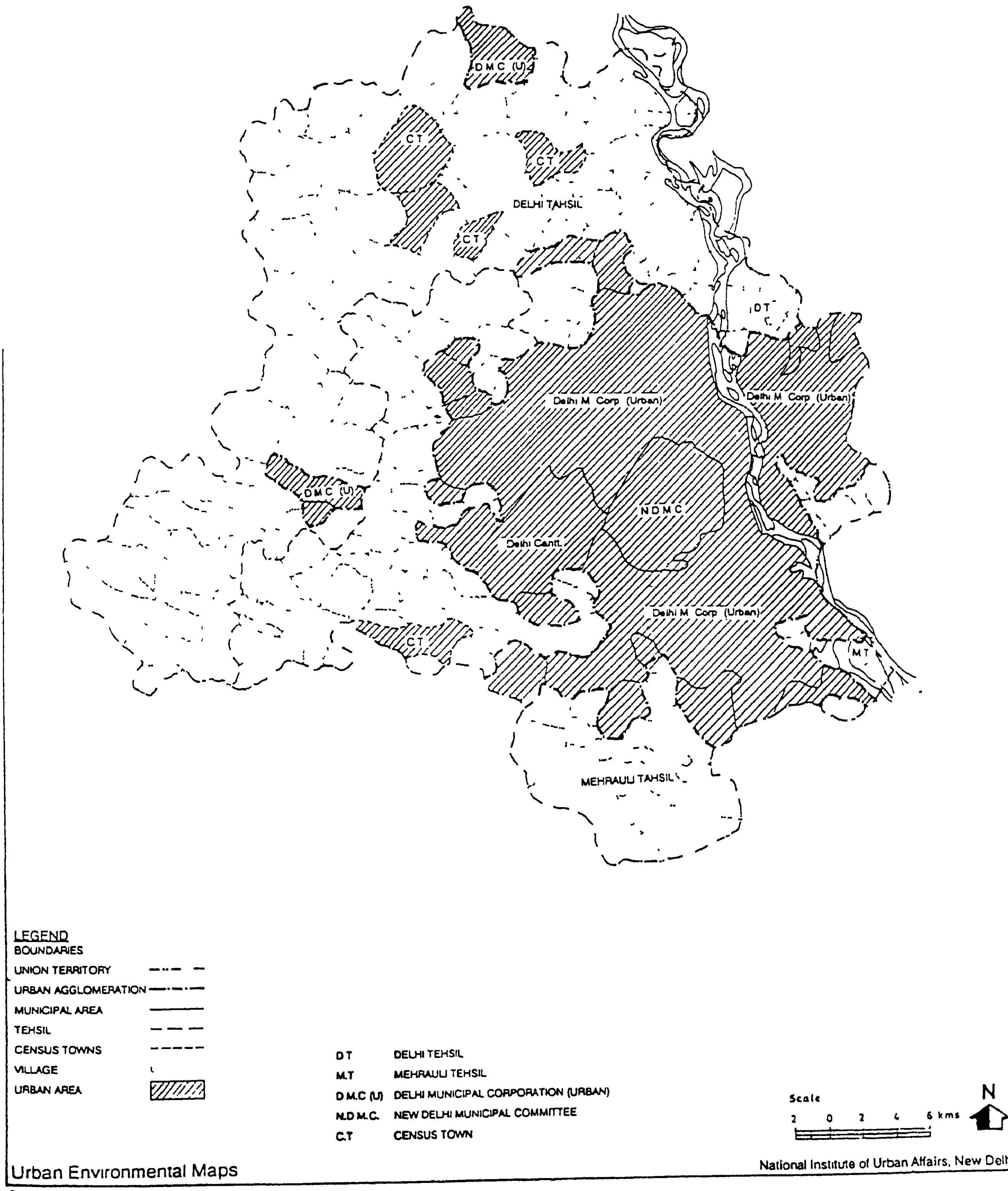
1 4.2 Housing and slums

Urban Delhi in 1981 accommodated about 11.5 lakh households in different types of housing - resettlement, squatter, unauthorized and others[5] As per the Master Plan for Delhi (1981-2001) another 13 lakh households would be added to the existing ones by the year 2001

There has been continuous growth in slum population in all metropolitan cities in the country. Delhi occupies the third position with respect to slum population with 32 lakh persons residing in slum areas In 1981, 31.4 percent of Delhi's population was residing in slums which increased to 32.8 percent in 1990[6].

Fig. 1.1. DELHI

Union Territory



Urban Environmental Maps

National Institute of Urban Affairs, New Delhi

Source Census of India (1981).

1 4.3 *Infrastructure development*

Industrial units in Delhi have increased from 62,000 in 1984-85 to 85,000 in 1991[7] The transport sector had an annual growth of 10 percent in the last two decades (1970-1990). Motorized vehicles have increased to 1.9 million from 0.2 million in 1971 Installed capacity of electricity in Delhi increased from 258 MW in 1985-86 to 607 MW in 1992-93 (about two and a half times increase). Despite this impressive growth in the power sector, there is a net deficit during the peak hours and Delhi Electric Supply Undertaking has to resort to power cuts in different parts of the city

The increasing pressure on urbanization is leading to progressive environmental degradation. Whether it is with respect to natural ecology or energy efficiency, there is a growing sense of breakdown in the urban fabric of the city. Therefore, there is a pressing need to evolve urban development parameters, standards, strategies in all sectors of economy for energy conservation

References

Chapter 1

1 Nanda, A R. 1991 Census of India 1991, Provisional Population Totals Rural - Urban Distribution, Series 1, Paper 2 of 1991 Registrar General and Census Commissioner, India.

2 GOI. 1988 Report of the National Commission in Urbanization, Volume II, Government of India, August

3 GOI. 1992 Census of India 1991- Delhi, District Census Handbook, Part XII A & B, Directorate of Census Operations, Delhi

4 National Capital Region Planning Board Interim Development Plan - 2001

5 Master Plan for Delhi (1981-2001) 1990 The Gazette of India, August

6 TCPO 1985. A compendium on Indian Slums, Towns and Country Planning Organization, New Delhi

7 Government of National Capital Territory of Delhi 1993 Delhi Statistical Handbook - 1992, Bureau of Economics and Statistics

Chapter 2

Scope and objectives

The overall scope of the study is to prepare an integrated energy conservation plan for the National Capital Territory of Delhi (in short Delhi). To develop the energy conservation plan for Delhi, the study has many limitations The relationship between energy use in Delhi across different sectors for various activities and spatial distribution are complex and mutually interactive. The understanding of the relationship is essential for the formulation of public policies and implementation of energy and urban development programmes. This would help in understanding the cross sectoral linkages that exist in the planning and implementation process

The basic objective of the study are to

- collect and compile data on supply and demand of energy in Delhi from pilot surveys, data collected from secondary sources and assumptions and norms;
- analyze the structure of urban energy consumption pattern in the four major sectors - domestic, transport, commercial and industry - for various energy using activities;
- to project energy demand for 2001 in the domestic and transport sector,
- study the energy supply pattern in different sectors and to project energy supply potential for 2001;
- identify the energy conservation potential for major end-uses in different sectors,
- prepare sector-wise energy conservation plan and then integrate various sectoral plans into an integrated energy plan for Delhi which would also contain policy guidelines and recommendations; and
- analyze various related factors and policies that may have a bearing on energy conservation programmes - sector-wise in conformity with the Master Plan for Delhi - 2001 A D.

2.1 Coverage of the study

In this study an attempt has been made to analyze the structure of energy use pattern in different sectors of Delhi. End-use analysis is carried out to the extent possible with the available information. Apart from looking at consumption patterns of the energy in different sectors and the changes that have taken place over time, various factors and policies that have a bearing on energy demand patterns is also analyzed Energy demand estimates for domestic and transport sector have been made for 2001 by analyzing data from primary, and secondary surveys and also using assumptions and norms. On the other hand, supply potential of various types of energy sources have been examined for 2001 by analyzing time series data. Finally, different policies and programmes that can be undertaken in Delhi to use energy most efferent sectors are developed in order to come out with an integrated energy conservation plan for Delhi.

2.2 Project status

2.2.1 Tasks completed

The major activities that has been completed under different sectors over the last one year is presented below.

Domestic sector

- Compilation of data on energy consumption pattern in the domestic sector for six major end-uses across various income groups. The end-uses include, cooking, and "other"[a]. The data was collected in May-July 1989 by the Tata Energy Research Institute (TERI) using a pre-tested household schedule;
- Analysis of energy use by fuel type and end-use;
- Variation in energy consumption pattern by income class;
- Ownership of electrical appliances and extent of their use;
- Shifts in consumption pattern of fuels over time;
- Estimation of energy demand and its mix for the years 1989 and 2001,
- Analysis of commercial energy supply pattern using time trend equation.

Transport sector

- Compilation of data on growth of road based motorized vehicles and its composition, traffic movement on major roads, occupancy levels, vehicle utilization pattern, fuel efficiency norms and modal split using data from secondary sources;
- Analyze TERI household survey data of 1989 to understand how residential location and household income affect trip rates, travel patterns and modal choice Only passenger modes of transport have been considered in the analysis;
- Analysis of travel characteristics for different purposes upto work place, work related and education;
- Shifts in mode of travel over time and reasons for the same;
- Role of public transport and policies relating to the same;
- Estimate total energy demand by different vehicles for the years 1991 and 2001.

Commercial sector

- Development of a methodological framework for carrying out a questionnaire based energy use survey of (a) retail shops of different types spread over different parts of Delhi, and (b) different categories of hotels (ranging from five star deluxe to the ordinary ones);
- Design of questionnaires and its pre-testing,
- Collection of data from 450 retail shops of various types and also from 20 hotels on energy consumption pattern and efforts taken towards energy conservation using random survey method;
- Compilation of data on consumption of energy by end-use and the scope for energy conservation separately for shops and hotels;

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[a] The "others" category includes the use of such electrical appliances like irons, washing machines, exhaust fans, refrigerators, water pumps, mixers/grinders and televisions that are not included under the specific end-uses mentioned earlier

- Analysis of energy consumption norms for lighting in different categories of retail shops in Delhi.

Industrial sector

- Compilation of data on growth of number of registered industries and their energy consumption pattern using the Annual Survey of Industries data published by the Central Statistical Organization.

2.2.2 Tasks remaining

Following activities are presently being carried out under this project, results of which will be submitted in the draft final report by end of July'94.

- Analysis of energy consumption pattern in the commercial sector (shops and hotels) for various end-uses;
- Analysis of energy consumption pattern for some energy intensive industrial units;
- Development of an integrated energy conservation plan for the National Capital Territory of Delhi, which would also contain policy guidelines and recommendations This would be done for separately for each of the sectors; and
- Analyze various related factors and policies that may have a bearing on energy conservation programmes - sector-wise in conformity with the Master Plan for Delhi - 2001 A D.

2.3 Organization of the report

This interim report presents the progress of the project till March 31, 1994 The report is divided into seven chapters. First chapter introduces the study for the city of Delhi. The second chapter gives the scope, objectives and coverage of the study The third chapter discusses the methodology adopted in this study. The fourth chapter examines the energy consumption pattern in households for various end-uses and across different socio-income groups Estimates of domestic energy demand have been made for the two reference years 1989 and 2001 Demand estimates have been compared with the energy supply figures. The chapter five analyzes the transportation pattern in Delhi and factors influencing passenger travel demand. Estimation of energy demand has also been presented for 1991 and 2001. Transport energy demand estimates have been compared with the supply figures. The chapter six on commercial sector, examines the relationship between plinth area and electricity demand for lighting in different categories of shops based on survey data collected from about 450 retail shops in Delhi.

Chapter 3

Methodology

For developing an energy conservation plan in the city of Delhi, first, it is essential to analyze the energy consumption pattern in different sectors. In each sector there are various details which one can get into but the main focus should be on the various factors that affect the energy consumption and the roles of each of these factors and the relationship with other sectors in terms of energy consumption. This case study of Delhi has concentrated on four sectors - domestic, transport[a], commercial and industry.

3.1 Domestic and transport sector

Households consume energy for various end-uses. These include cooking, water heating, space cooling, space heating, lighting and "others". The "others" category includes the use of such electrical appliances like irons, washing machines, exhaust fans, refrigerators, water pumps, mixers/grinders and televisions that are not included under the specific end-uses mentioned above.

In the domestic sector, income is one of the major determining factors in deciding the energy mix and the consumption of various sources of energy. Studies have shown that energy consumption is income elastic[1,2,3]. Therefore, an income-wise analysis of energy use in the domestic sector has been carried out in this study.

The urban households in Delhi (leaving aside the slum population) consume primarily three types of energy sources, viz., electricity, kerosene and LPG. Cooking and water heating is done by a combination of LPG, kerosene and electricity, the mix of which differs across income classes. Lighting demand is mainly met by electricity, but the lowest income households also use kerosene. Space cooling, heating and "others" are done by only electrical appliances

Size of a household also influence energy consumption pattern. As the family size increases, the need for energy also increases. Thus, energy consumption pattern in the domestic sector has been analyzed on per-capita basis.

In the case of transport sector, the study considers only passenger modes of transport and not freight modes. Energy use in this sector is mainly met by petrol or motor spirit and diesel oil. To understand the energy requirements in the transport sector, travel demand in a city needs to be analyzed Urban travel demand depends on two parameters. The first is the volume of passenger trips. This depends on the size (in terms of urban population) and the economic structure of the city. The second parameter is the average length of each trip. Trip length depends on the form and structure of the urban area and the land use pattern. Both these parameters - trip rate and trip length - can be assumed to depend on the distance of the residential areas from the Central Business District (CBD). A study carried out in the city of Delhi by Maunder[4] reveals that trip length increases while trip rate decreases with

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[a] Due to lack of data on flow of goods traffic in Delhi and the energy consumption pattern, the transport sector is restricted to passenger modes only

increasing distance of locality from the CBD. This affects the energy consumption pattern in the transport sector.

The Tata Energy Research Institute (TERI), New Delhi, conducted an urban household energy survey in the city of Delhi during 1989. The basic aim of the survey was to:

- estimate energy consumption by end-use across different income groups in the domestic sector, and
- understand the factors influencing the travel demand and thereby energy consumption pattern in different residential areas in Delhi.

It was, therefore, essential to stratify the sample into various income groups and different locations in the city of Delhi. However, as information on distribution of households according to various income groups was not available, the electricity consumption bill was used as a surrogate variable to the income level of a household. It was assumed that a household with a relatively higher income level would have higher electricity consumption (see Annexure 3 1). Also, to assess how distance may affect travel characteristics in terms of choice vis-a-vis mode of transport, trip length and trip rates by purpose, different residential areas were chosen, keeping in view their distance from the CBD, namely connaught Place (Figure 3.1). Thus, the sample design is formulated by considering the two basic parameters: (i) electricity consumption bill and (ii) location of residential areas with respect to distance from the CBD

3.1.1 Survey areas

Delhi Electricity Supply Undertaking's (DESU's) help was sought in selecting representative households for the survey which was based on electricity consumption bill. DESU has divided Delhi into a number of districts and maintains complete computerized information on the monthly electricity consumption of each household. During 1989, there were 24 districts under DESU and these districts were grouped on the basis of their distance from the CBD, namely, Connaught Place.

From DESU, information was collected on electricity consumption for three districts - each located at different distances from the CBD (Table 3 1) These were Janakpuri, R.K Puram and Paharganj located at large, medium and short distances, respectively, from the CBD (Figure 3.1).

Table 3.1 Survey areas and their distances from the CBD

District of residential area	Distance from CBD (km)
1 Janakpuri (JP)	20-25
2 R K Puram (RKP)	12-15
3 Paharganj (PG)	5

Janakpuri is one of the largest residential areas in Asia and situated to the west of Delhi, about 22 km from the CBD. Developed by the Delhi Development Authority (DDA), Janakpuri comprises of bungalows, houses and 3-5 storeyed flats All residents have at least two rooms and most have four to six rooms.

R K Puram is situated to the south of Delhi and is about 14 kms from the CBD Mainly the residential area of Government officials, it is divided into different

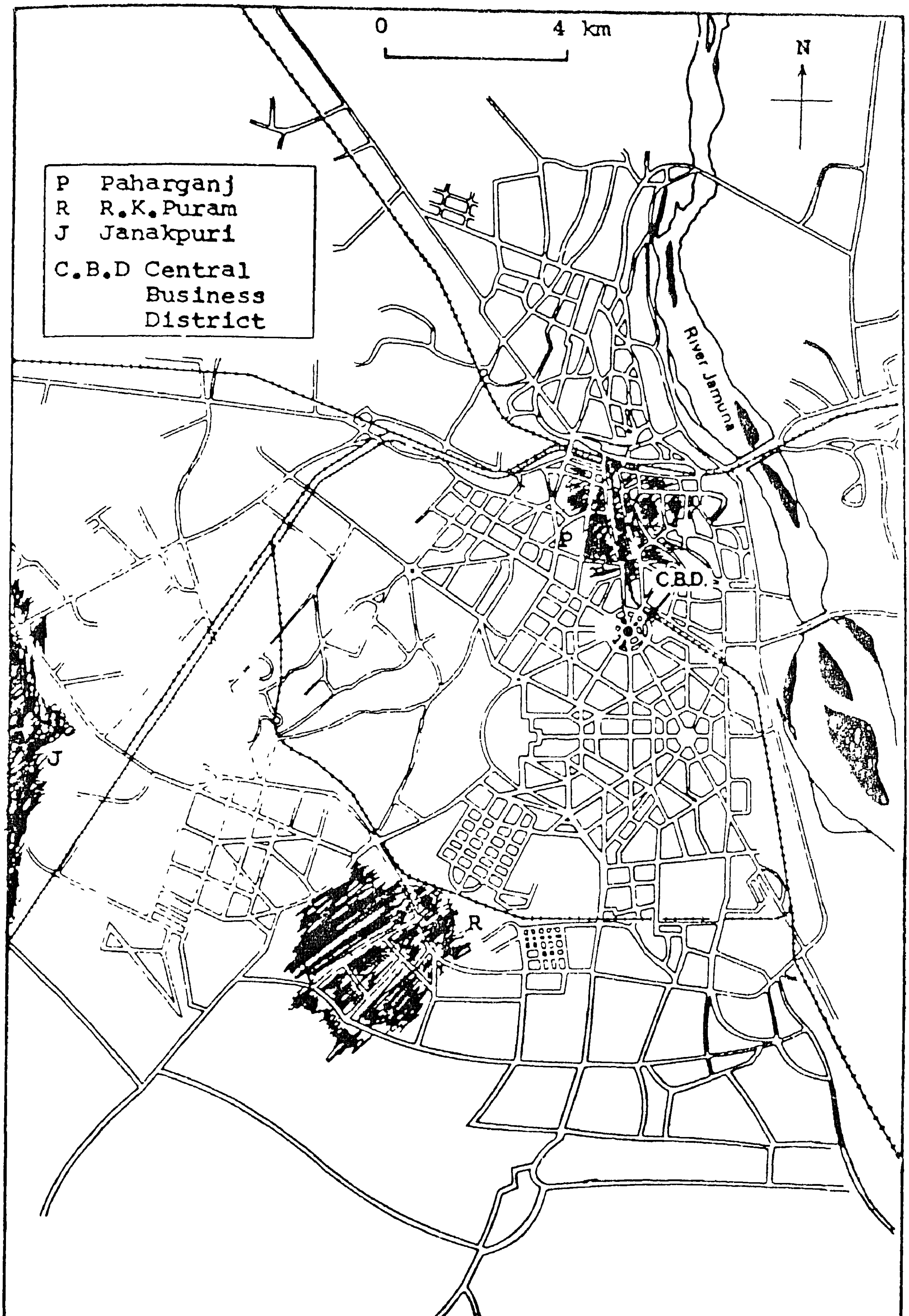


Figure 3.1 Location of study areas in Delhi

blocks or sectors. Households within each block are homogeneous but across the blocks they are heterogeneous in terms of dwelling size and shape

Paharganj is essentially a commercial area located at the short distance north of the CBD. It is unplanned, with narrow lanes and dense residential clusters. Dwellings tend to have an average of three rooms.

DESU has classified the consumers in each district into nine groups, which are also called cycles. Each of these cycles comprise a different cluster of settlements within a district. Cycles 1 to 8 are billed once in two months, whereas consumers in cycle 9 are billed every month Cycles 1 to 4 are billed in the odd months whereas 5 to 8 are billed in the even months. For our survey design, only four cycles had been considered from each of the three selected districts, mainly because of the lack of time and delay in obtaining data from DESU The distribution of households in the selected districts - R K Puram, Janakpuri and Paharganj, according to the electricity consumption bill is presented in Table 3.2. This was essential for determining the sample size of the households, as is described in the next section

Table 3.2 Distribution of total number of households in four different cycles

Units consumed (kWh)	RKP	JP	PG	Total
Upto 100	3511 (16 7)	5323 (18 2)	18348 (29 7)	27184 (24 2)
100-200	2586 (12 3)	3880 (13.2)	7112 (11.5)	13578 (12 1)
over 200	14985 (71.0)	20110 (68 6)	36410 (58 8)	71505 (63.7)
Total	21082 (100)	29313 (100)	61870 (100)	112267 (100)

Figures within parentheses indicate the percentage distribution

The electricity consumption bill in Table 3.2 is used as a proxy to income of a household, as described earlier. It is, therefore, assumed that the households selected in the three electricity consumption class represent low, middle and high income households, respectively (Annexure 3 1)

3 1 2 Determination of sample size

Let a_{ij} denote the total number of households in the i^{th} electricity consumption class located in the j^{th} district.

where, $i = 1$ (upto 100 kWh); $i = 2$ (100-200 kWh)

$i = 3$ (over 300 kWh) and

$j = 1$ (RKP), 2 (JP) and 3 (PG)

The value of a_{ij} is known from Table 3.2 (As an illustration $a_{2\,3} =$ 7112).

n_{ij} denotes the total number of households to be surveyed in the j^{th} location and belongs to i^{th} electricity consumption class.

The total sample size was targeted around 900 households (to be more precise, 889 households). Then n_{ij} was determined by the method of proportional allocation as given below.

$$n_{ij} = \frac{a_{ij}}{A} \times 889 \qquad (1)$$

where,

$$A = \sum_i \sum_j a_{ij} = \textit{total number of households} \ (= 112267) \qquad (2)$$

Thus,

$$\sum_i \sum_j = \textit{total sample number of households for survey} \ (= 889) \qquad (3)$$

Using equation (1), the proportional allocation of the sample distribution of 899 households in the three selected districts according to electricity consumption class were determined for the household survey and is given in Table 3 3

Table 3.3. Distribution of sample number of households selected for the survey

Units consumed (kWh)	RKP	JP	PG	Total
Upto 100	31	47	168	240
100-200	20	30	55	105
over 200	114	153	277	544
Total	165	230	494	889

A total of 165 households were randomly surveyed in R K Puram, 230 in Janakpuri and 494 in Paharganj.

3 1 3 Survey method

Six investigators were hired and trained for conducting the survey which was carried out using the method of stratified random sampling. The distribution of households in three different strata as given in Table 3 3 was used for data collection by the six investigators Households in the identified districts were randomly surveyed using a pre-tested household schedule (Annexure 3.2). Data was obtained on the domestic energy consumption pattern and also on travel characteristics from the randomly surveyed households. Method of users' recall was used for collecting the relevant information, the reference period of data collection was May-July 1989 The households interviewed were representative of different dwelling types found in the three districts To ensure reliability of the data collected, 10 percent of the households surveyed were randomly cross-checked by our personal visits in each of the three districts

A detailed explanation of the type of data collected using the household schedule (Annexure 3.2) is given below:

Section A General information
This section basically draws out information pertaining to the household family size, number of rooms, plinth area, number of persons engaged in various activities and the level of income of the household. It seeks to establish a correlation between the income and the energy consumption pattern in the domestic sector.

Section B Domestic activities
B1 - This provides information on the different types of fuel, the quantity used and the time spent for various end-use activities
B2 - This section aims at finding out whether there has been a shift in the type of fuel used for various activities over the past five years.
B3 and B4 - These sections together provide information on the monthly electricity consumption attributable to various household appliances

Section C Travel characteristics
C1 and C2 - These sections seek to measure the comparative fuel efficiency of different vehicles i.e. smaller cars vis-a-vis motorcycles in terms of fuel consumption, mileage, average occupancy, transportation cost, and distance travelled Through this section, travel patterns were identified. Data was collected on modal choice, distance and time spent travelling for the daily trips undertaken by the household members Finally, information was sought on the number of persons who had shifted from private to public modes of transport and vice versa and the reasons for the same.

3 1 4 Data analysis
The data collected from a total of 889 households was compiled, processed and analyzed using LOTUS 123 spreadsheet software on an IBM PC/AT computer In the domestic sector, data was analyzed for four income categories, keeping in mind our basic objectives of estimating energy consumption by end-use, by type of activities/devices and the fuel mix pattern in these income categories The four monthly household income classes considered for data analysis are

Class I - income upto Rs 1500;
Class II - between Rs 1500 and Rs.3000;
Class III - between Rs 3000 and Rs.4500;
Class IV - over Rs.4500.

In the transport sector, the travel-related parameters, viz. trip length, trip rate, travel time were analyzed both with respect to the household income level as well as the location of the residential settlements.

Table 3.4 presents the number of households that were surveyed in the four income classes in the three selected districts of Delhi.

Table 3.4 Distribution of households surveyed in different districts of Delhi across various income categories

District	Monthly income class Rs./hh	Income class	Household surveyed		Avg. family size
			Number	%	
PHG	upto 1500	I	81	16.4	4.5 (1.5)
	1500-3000	II	230	46 6	4.5 (1.7)
	3000-4500	III	57	11 5	4 3 (1.5)
	over 4500	IV	126	25.5	4 7 (1 9)
	All together	All	494	100	4 5 (1 7)
RKP	upto 1500	I	17	10 3	4 8 (1 6)
	1500-3000	II	43	26.1	4 6 (1.5)
	3000-4500	III	24	14 5	4 2 (1 1)
	over 4500	IV	81	49 1	4 4 (1 0)
	All together	All	165	100	4 5 (1 3)
JP	upto 1500	I	50	21 7	5 6 (1.6)
	1500-3000	II	54	23 5	4 6 (1 9)
	3000-4500	III	46	20 0	4.3 (1 2)
	over 4500	IV	80	34 8	4 8 (1.6)
	All together	All	230	100	4 8 (1.7)
All together	upto 1500	I	148	16.6	4 9 (1 6)
	1500-3000	II	306	34 4	4.6 (1 7)
	3000-4500	III	148	16 6	4 3 (1 4)
	over 4500	IV	287	32 3	4.7 (1 6)
	All together	All	889	100	4 6 (1 6)

Figures within parentheses indicate the standard deviation

3 1 5 Estimation of energy demand in the domestic sector

Total household energy consumption is computed by adding up the gross product of total per capita fuel consumption in each income class with different population weights The weights are proportional to the share of population belonging to each income group. Due to non-availability of data on income-wise distribution of population, the following method is used to determine the population weights in each of the four income categories

From the National Sample Survey (NSS) estimates[5] the share of total population in urban Delhi with monthly household income more than Rs.1500[b] went up from 17% in 1978 to 32% in 1983 - annual growth rate of 13.5% Assuming the same growth rate, it is estimated that during 1989/90, nearly 78% of the total population in urban Delhi were having household income more than Rs.1500 per month. In other words, nearly 22% of the total population in urban Delhi were having household income less than Rs.1500 per month, during 1989 But the distribution of 78% of the population across the three higher income categories are unknown. To determine population weights in each of the four income classes during the period 1989, the following simultaneous equations have been solved.

$$\sum_{i=1}^{4} x_i = P \tag{4}$$

$$x_1 = 0.22P \tag{5}$$

$$\sum_{i=1}^{4} f_{ij} x_i = S_j \qquad for\ j = 1,2,3 \tag{6}$$

$$x_i > 0 \qquad for\ i = 1,2,3,4 \tag{7}$$

where.

x_i = the distribution of population in the i[th] income class, which is to be determined.

i = 1 (upto Rs.1500 as household monthly income),
2 (Rs.1500 - 3000);
3 (Rs 3000-4500),
4 (over Rs 4500)

P = number of electricity consumers in urban Delhi during 1989[c]

f_{ij} = annual per capita j[th] fuel consumption in the i[th] income category, where i = 1,2,3,4 and j = 1 (LPG), 2 (Kerosene), 3 (Electricity)

S_j = total sales of j[th] fuel in the domestic sector. where j = 1,2,3

These simultaneous equations have been solved for the year 1989, to obtain the most <u>ideal</u> distribution of population across the four income categories (i e x_is are

---

[b] NSS data provides the distribution of population in urban Delhi for different expenditure blocks On adding the national savings rate of 20% of each of the expenditure blocks, household income is computed

[c] Total urban population in Delhi during 1989 was 8 7 million. Nearly 71% of this total population (i e 6 17 million) were consumers of electricity. The remaining 29% of the population were staying in slums and in resettlement colonies (mostly located in the trans-Yamuna areas) where household electricity connection was not available Since the entire analysis is restricted to households with electricity connection, the total urban population of Delhi during 1989 is taken as 6.17 million.

estimated). On multiplying these estimated population weights with per capita annual fuel consumption, the total energy consumption profile in the domestic sector is constructed for 1989.

Energy demand in the domestic sector for 2001 is done by changing the population distribution of households across the same income categories due to migration and keeping the per capita energy consumption norm for 2001 the same in the four income blocks as was estimated for 1989. The assumption on migration across the income the same income classes have been done by looking at the planned poverty alleviation programme given in the Seventh Five Year Plan Document[6]. The transition of the people across the poverty line from the lowest income group to the higher ones is estimated by using a sub-model. According to this sub-model, it is assumed that the number of households will shift from income class I to class II according to 6.97% for urban areas. Further, it is assumed that the number of households will shift from income class II to class III and then to class IV at the rate of 3 02%. Using these migration rates, the population distribution in the four income classes are computed for 2001. The total urban population in Delhi (excluding slums population) during 2001 is estimated as around 10.01 million.

Further, on multiplying the per capita annual fuel consumption with that of the projected population distribution across different income classes, total energy requirement in the domestic sector is estimated during 2001. The estimated values of x_is are given in Table 3.5 for the two periods 1989 and 2001.

Table 3.5. Estimated population weights in Delhi

Income class (i)	**x_i (10^6 persons)**		**Population weights**	
	1989	**2001**	**1989**	**2001**
1 (upto Rs.1500)	1 36	1 70	0 22	0 17
2 (Rs.1500-3000)	2.47	3.80	0 40	0 38
3 (Rs.3000-4500)	2 22	3 80	0.36	0.38
4 (over Rs.4500)	0.12	0 70	0 02	0 07
All together	6.17	10.00	1.00	1 00

Finally, the estimated total energy demand for the domestic sector during 1989 and 2001 is examined with the corresponding year's energy supply statistics in Delhi.

3 1 6 Estimation of energy demand in the transport sector

Energy demand in the transport sector can be either estimated from the supply side or or from the demand side. From the demand side, the transport energy demand depends on the population, size of the city and per-capita trip rate. On the supply side, energy demand depends on various modes available, their population, vehicle utilization and occupancy level In this study, energy demand is estimated from the supply side using the following mathematical equations:

$$E_i = V_i \times U_i \times O_i \times F_i \tag{8}$$

Where,

E = annual energy demand
V = number of vehicles
U = average annual vehicle utilization
O = average occupancy level
F = average operating energy intensity[d 7]
i = type of passenger vehicle

The total energy demand in the transport sector is obtained by aggregating the fuel consumption by each mode of transport Fuel demand in the passenger transport sector of Delhi is estimated by assuming that the present trends of vehicle growth in Delhi will continue, but the fuel efficiency norms, annual utilization and occupancy levels of vehicles will remain unchanged at the present level.

The energy demand estimates are then compared with the projected sales of petroleum products - petrol and diesel to understand the supply-demand gap in 2001

3.2 Commercial sector

Schools, hospitals, private business, hotels, shops, restaurants, Government establishments that are not included in domestic, transport, agriculture and industrial sectors comprise the commercial and services sector. In this study commercial sector includes different kind of retail shops and hotels spread over different parts of Delhi

There were more than 3 lakhs shops and about 500 residential hotels spread all over Delhi in 1989 Table 3.6 gives growth of shops and hotels in Delhi from 1987 to 1989[8]

Table 3.6. Growth of shops and residential hotels in Delhi (1987-89)

				Growth rate (%)	
Particulars	**1987**	**1988**	**1989**	**1987-88**	**1988-89**
Shops	285129	292915	304096	2 73	3 82
Residential hotels	490	488	490	-0 41	0 41

3 2 1 Primary survey in retail shops

The Tata Energy Research Institute, New Delhi, carried out a primary survey in a large number of retail shops in Delhi during the period September-October 1993 The objective of the survey was to collect data on energy consumption pattern using

[d] The operating energy intensity represents the fuel efficiency of different modes of vehicles It measures the amount of energy needed to move 1 person over 1 km by a given vehicle When these measures are averaged for an entire system, they are described as 'energy intensity' of a mode. Operating energy intensity of a vehicle, therefore is an average concept, which conceals wide variations in energy intake in operating conditions and is expressed in l/pkm

a pre-tested questionnaire from different categories of shops spread over various parts of Delhi.

A two-step random sampling method was used to collect the necessary information.

(a) Market structure

At the first step, due to lack of data on the distribution of various types of retail shops in different markets, information on type and number of shops was collected from nine major markets using a one page pre-tested questionnaire given in Annexure 3.3. The nine markets were - Palika Bazar, Laxmi Nagar Bazar, Sarojini Nagar Market, Lajpat Nagar Market, Khan Market, Karol Bagh Market, Tilak Nagar Market, Khanna Market and Shahdara Market. Table 3.7 gives the distribution of total number of shops in the nine markets surveyed. These markets contained 2679 retail shops

Table 3.7 Distribution of Shops in Nine Markets of Delhi

Category of shops	Markets surveyed										
	Palika Bazar	Laxmi Nagar Bazar	Sarojini Nagar Bazar	Lajpat Nagar Bazar	Khan Market	Karol Bagh Market	Tilak Nagar Market	Khanna Market	Shahdara Market	Total	%age breakup
TEXTILE	110	40	56	270	12	233	54	21	90	886	33 07
AUTO PARTS		13	1	13	2	3		5		37	1 38
FOOD ARTICLES											
Fruits & vegetables			15	11	2	1		3		32	1 19
Grocery	14	10	5	29	9	5		8	73	153	5 71
Foodgrains			10	6				14	2	32	1 19
Oil & ghee		1		2					10	13	0 48
BUILDING MATERIALS											
Hardware		33	1	10				3	11	58	2 16
Iron & steel		5		4					15	24	0 89
Timber & Plywood		3		1					3	7	0 30
CONSUMER GOODS											
Cosmetics & toiletries			5	45		26		1	30	107	3 99
Footwear	30	8	30	40	4	25	4	5	17	163	6 10
Electrical goods	65	17	11	13		4	8	12	15	145	5 41
Medicines & chemicals		7	6	9	4			3	4	33	1 23
Rubber & plastics		5	5	7	4	3		1	3	28	1 04
Hosiery			10	2	1	11			4	28	1 04
Books & stationary		2	5	5	6	5		4	9	36	1 34
Bicycle, tyres & tubes		6	2	8	1	2		3	5	27	1 00
Furniture & fixtures		3	8	12		3		1		27	1 00
Crockery & utensils		1	9	23	5	10		3	5	56	2 09
Radio & television	38	15	7	14	7	2	2	1	1	87	3 25
Optical & watch	20	6	10	15		11	1	4	14	81	3 01
Pan & cigarette	1	9	5	8	1			1	8	33	1 27
Flour mill			2	1	3			5	3	14	0 52
Barbar shop		2		4		1		2	2	11	0 41
Photo studio/ Xeroxing	1	15	5	10	10	3	2	2	1	49	1 83
Others	15	123	10	63	23	56		5	112	407	15 19
RESTAURANT		17	10	12	5	15	13	4	29	105	3 91
TOTAL SHOPS	294	341	228	637	99	419	, 84	111	466	2679	100 00%

(b) Survey of retail shops

At the second stage, a primary survey was carried out in different types of shops spread over 11 markets. A questionnaire given in Annexure 3.4 was used to collect data on energy consumption pattern in different shops.

A total of 450 shops were fixed as the sample size for data collection purposes. The 450 shops were first distributed into various categories based on the market composition of shops as obtained in Table 3.7. Table 3.8 gives the total number of shops of various types surveyed in the 11 markets. Markets surveyed include - Pakika Bazar, Sarojini Nagar Market, Tilak Nagar Market, Gopinath Bazar, Shahdara Market, Laxmi Nagar Market, Azadpur Market, Karol Bagh Market, Kingsway Camp Market and Moti Nagar Market

Table 3.8. Composition of different types of shops Surveyed

Category of shops	Percentage distribution	Total No. of Shops Surveyed
TEXTILE	34 00	154
AUTO PARTS	2.65	12
FOOD ARTICLES		
Fruits & vegetables	3.97	18
Grocery	1.76	8
Oil & ghee	0.22	1
BUILDING MATERIALS	3 31	15
CONSUMER GOODS		
Cosmetics & toiletries	3 97	18
Footwear	7 95	36
Electrical goods	4 41	20
Medicines & chemicals	2.21	10
Rubber & plastics	0.22	1
Hosiery	0.44	2
Books & stationary	1.10	5
Furniture & fixtures	3 31	15
Crockery & utensils	2 43	11
Radio & television	1.32	6
Optical & watch	3.76	17
Flour mill	0 66	3
Barbar shop	0 22	1
Photo studio/Xeroxing	2 87	13
Jewellery	6 41	29
Others	7 73	35
RESTAURANT	5.08	23
TOTAL SHOPS	100.00	453

(c) Survey method

Four investigators were hired and trained for conducting the survey. The distribution of shops as given in Table 3.8 was used for data collection. Shops in the 11 identified markets were randomly surveyed using a pre-tested questionnaire presented

in Annexure 3.4. Method of users' recall was used to collect the relevant information. The reference period of the survey was October-November 1994.

The questionnaire given in Annexure 3.4 is divided into six sections. First section provides the general information about the shop. In the second section, to understand the variation in electricity consumption pattern in summer and winter months, average monthly expenditure on electricity in the two seasons have been collected. Section three, gives a detailed profile of electricity consumption for five major end-uses. These include, lighting, space cooling, space heating, water heating and others. In section four, information on usage of captive gensets (if, in use) is collected. Information on energy (other than electricity) usage patterns is collected in section five. The last section six is on what kind of measures the shopkeepers have taken for saving energy use

3 2.2 Primary survey in hotels

A questionnaire based survey was carried out in 20 hotels spread over different locations in Delhi While selecting these hotels for survey, following two criteria was used:

(1) type of hotel (by star category)

(2) ownership pattern - whether government owned or privately owned

Before identifying the hotels for survey, information was collected from the Federation of Hotel and Restaurant Association of India about name, type, location and ownership of different hotels spread over different parts of Delhi On the basis of this information, purposive selection of hotels were done under different categories and their ownership pattern Table 3 9 presents the list of hotels surveyed by the Tata Energy Research Institute, New Delhi.

Table 3.9. List of hotels surveyed in Delhi

Hotels	**Location**	**No. of rooms**	**Ownership pattern**
5 star delux			
1 Ashoka Hotel	Chanakyapuri	571	ITDC
2. Holiday Inn	Connaught Place	500	Private
5 star			
3 The Claridges	Aurangzeb Road	164	Private
4 Samrat Hotel	Chankyapuri	247	ITDC
5 Hotel Janpath	Connaught Place	213	ITDC
6 Nirula's Hotel	Connaught Place	29	Private
3 star			
7. Hotel Broadway	Asaf Ali Road	32	Private
8. Hotel Marina	Connaught Place	94	Private
9. Hotel York	Connaught Place	27	Private

Table 3.9 (Contd.). List of hotels surveyed in Delhi

Hotels	**Location**	**No. of rooms**	**Ownership pattern**
2 star			
10. Hotel Flora	Daryaganj	24	Private
11 Hotel Manor	Friends Colony	18	Private
12. Hotel Metro	Connaught Place	10	Private
1 star			
13. Hotel 55	Connaught Place	15	Private
14. Hotel Host Inn	Connaught Place	10	Private
15 Hotel Neeru	Daryaganj	24	Private
Government approved			
16. First Hotel	Karol Bagh	30	Private
17 Hotel Gautam	D B Gupta Road	64	Private
18. Hotel Jukaso Inn	Connaught Circus	40	Private
19. Palace Heights	Connaught Place	18	Private
20. South Indian Hotel	Ajmal Khan Road	25	Private

Four investigators were hired and trained for collecting energy consumption data from different hotels. Data was collected using a pre-tested questionnaire as given in Annexure 3 5 At least 5 trips were made by the investigators in each hotel to get the questionnaire completely filled in. The reference period of the survey was November-December 1993.

Questionnaire on hotels is divided into two sections. First section provides the general information of the hotel. While information on electricity usage, inventory of electrical appliances, captive gensets in use, generation of food waste daily and conservation measures is collected in the second section.

3.3 Industrial sector

Delhi has experienced a tremendous spurt in industrial activity during the last two decades However, the available data is woefully inadequate and out of date. The only published data on energy consumption pattern in industrial units is available in the Annual Survey of Industries (ASI), published by the Central Statistical Organization, Government of India The latest data is available for 1989-90. But the ASI data only covers the registered factories. Besides these registered factories, a large number of unorganized production and service activities known as 'informal sector' do exist in Delhi for which no data is available. Given the data limitations, the present study would analyze the energy consumption pattern in registered factories only.

According to the ASI data, Industries (registered factories) in Delhi consumes nine types of fuels. These include: coal, soft coke, LPG, firewood, charcoal, diesel,

furnace oil, other fuel oil and electricity. Energy use depends on the type of industry, production process, etc. Efficiency of energy consumption by industries is very complex. Industries producing the same product may consume energy in different ways, depending on the technology, age of plant, labour utilization, etc The appropriate method of analyzing industrial energy consumption would be to compare it with value added.[e]

The study would analyze the ASI data on energy consumption pattern and the total energy intensity in terms of value added for some selected registered factories where the volume of energy consumption is relatively high.

3.4 Energy units and conversion factors

To facilitate aggregation and comparison in dealing with different types of fuel, each energy source is converted to its equivalent calorific value. Table 3 10[9,10] presents the conversion of an energy unit to its corresponding calorific values for the energy sources consumed in the domestic and transport sector.

Table 3.10. Calorific value of different energy sources

Energy Source	kcal/kg	kcal/lit.	kcal/kWh
Liquefied petroleum gas (LPG)	10,800	--	--
Kerosene	10,600	8,600	--
Electricity	--	--	860
Diesel	11,435	9,720	--
Petrol	12,220	8,920	--

[e] Value added by manufacturing represents that part of the value of the product which is created in the factory during the manufacturing process It provides a measure of the contribution made by the resources of labour and capital in producing that output or activity It is obtained by deducting from the 'total value of output' the 'total value of input' and 'depreciation' and is expressed in Rupees.

References

Chapter 3

1 NCAER, 1985. Domestic Fuel Survey with special Reference to Kerosene - Volume I, National Council of Applied Economic Research, New Delhi.

2 Ganapathy, R S and G. Padmanabhan, 1985 Energy and Urban Development - The Case of Ahmedabad, Public Systems Group, Indian Institute of Management, Ahmedabad, December.

3 Dharmarajan, K. 1988. Urban Growth and Household Energy. Energy Policy Issues, 4 48-64, Tata Energy Research Institute, New Delhi

4 Maunder, D A C 1984. Trip Rates and Travel Pattern in Delhi, India, Transport and Road Research Laboratory, Research Report 1, Department of Transport, Berkshire, U K.

5 GOI 1986. National Sample Survey Thirty Second (1977-78) and Thirty Eight (1983) round of consumer expenditure survey Department of statistics, Ministry of Planning, Government of India

6 GOI. 1985-90. Seventh Five Year Plan - Vol. 1, Chapter 3, Planning Commission, Government of India, New Delhi

7 GOI. 1980 Report of the National Transport Policy Committee, Planning Commission, Government of India.

8 Delhi Administration. 1992 Labour Statistics 1992, Office of Labour Commissioner, New Delhi.

9 TERI. 1987 TERI Energy Data Directory Yearbook 1987, pp. 252, Tata Energy Research Institute, New Delhi

10 GOI 1986-87 Indian Petroleum and Natural Gas Statistics. Economics and Statistics Division, Ministry of Petroleum and Natural Gas, Government of India, New Delhi

Chapter 4

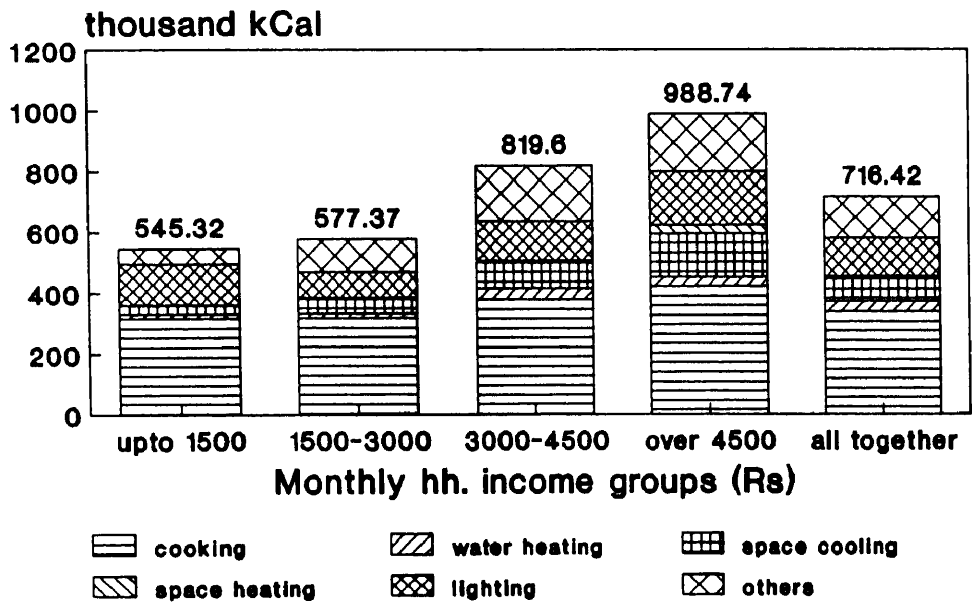
Energy demand in the domestic sector

The energy consumption pattern has shown an increasing trend with the rise in household income. This is mainly due to increase in the use of domestic electrical appliances like television, refrigerators, washing machines, water pumps, etc., particularly in the higher income households.

Primarily three types of energy sources are used in the domestic sector viz., LPG, kerosene and electricity In the low income households, less that 1 percent of the 889 surveyed households have reported the use of a very insignificant amount of firewood, soft coke and dung cake for cooking and water heating. These traditional fuels are mostly consumed by the poorest sections of the society - the majority of them are residing in the slum and resettlement localities of Delhi. As indicated earlier, the present study is restricted to non-slum population where consumption of traditional fuels is insignificant and this study, therefore, have not considered these fuels for analysis

Figure 4 1 gives the annual per-capita energy consumption for different end-uses across four income categories. Energy consumption level in the highest income households (over Rs.4500 per month was about double as compared to the lowest income households (upto Rs 1500 per month)

Fig.4.1. Annual per-capita energy cons. by end-use across income categories

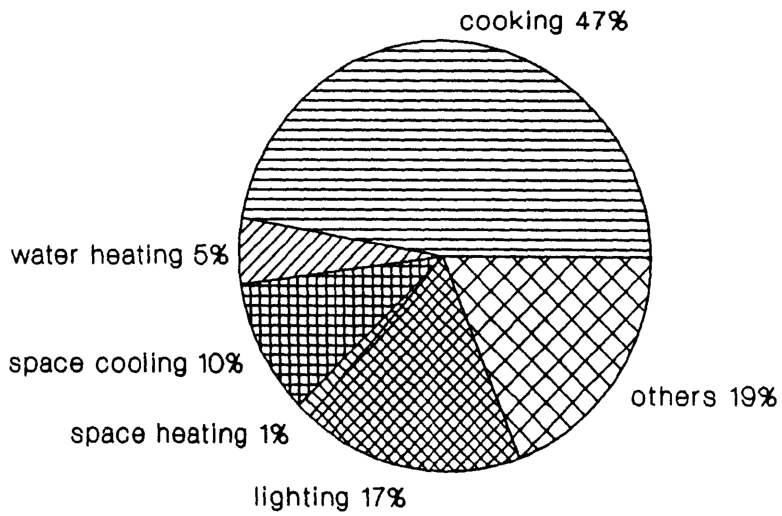


Variation in energy consumption was found to be the highest in the case of space heating between lowest and highest income households. In fact, between lowest and the highest income households there was a substantial increase in per capita energy consumption for space heating (about 28 times); space cooling (5 times)

and "others" (nearly 4 times). For lighting, the per capita energy consumption decreased from income class I to class II but thereafter the energy consumption level went up with increase in income. The reason is, in class households, some have reported the use of kerosene for lighting along with electricity, whereas households belonging to class II, III and IV used only electricity.

By pooling data for all the households, it is found that about 47 percent of the total per capita annual energy consumed (716,410 kCal) was for cooking (Fig. 4.2). The share of energy for other end-uses were - lighting 17 percent; space cooling 10 percent; water heating 5 percent; space heating 1 per cent and "others" 19 percent.

Fig.4.2. Energy share by end-use all together



Figures 4.3 to 4.6 show the share of energy for various end-uses across four income categories. The energy requirements in the lowest income group were mainly for cooking and lighting (Fig. 4.3). Nearly 58 percent of the total per-capita annual energy (545,320 kCal) was consumed for cooking. Lighting consumed nearly 25 percent of the total energy; space cooling 5 percent; water heating 3 percent and others 9 percent. No energy was consumed for space heating purposes in the lowest income class.

In income class II, share of energy for cooking was 55 percent of the average annual per capita energy consumption (577,370 kCal). This was followed by "others" (19 percent), lighting (14 percent); space cooling (8 percent); water heating (3 percent) and the remaining 1 percent went for space heating as shown in Fig. 4 4

The share of energy for cooking decreased in the third income group to nearly 46 percent, while the average annual per-capita energy consumption level went up to about 819,600 kCal. Energy share for other end-uses were - lighting 16 percent, space cooling 10 percent, water heating 4 percent, space heating 1 percent and "others" 22 percent (Fig. 4.5).

Fig.4.3. Energy share by end-use
Monthly hh. income: upto Rs 1500

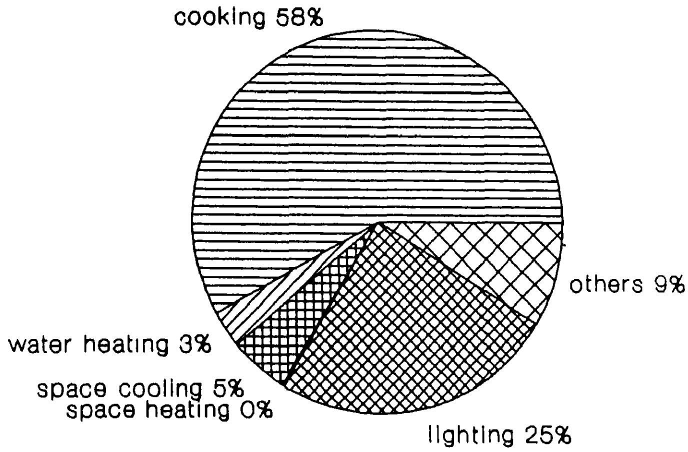


Fig.4.4. Energy share by end-use
Monthly hh. income: Rs 1500-3000

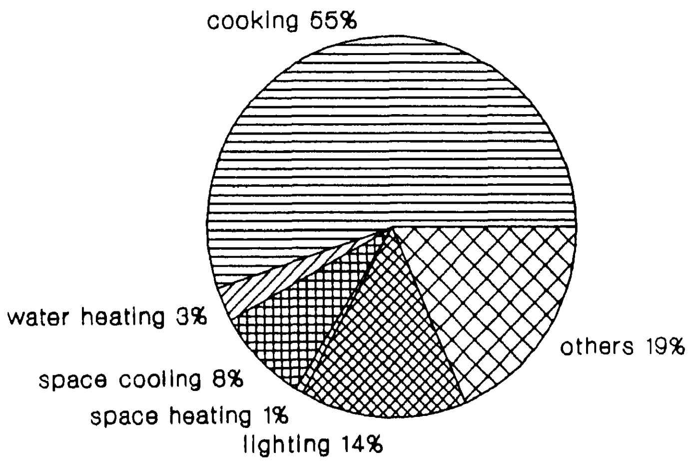


Fig.4.5. Energy share by end-use
Monthly hh. income: Rs 3000-4500

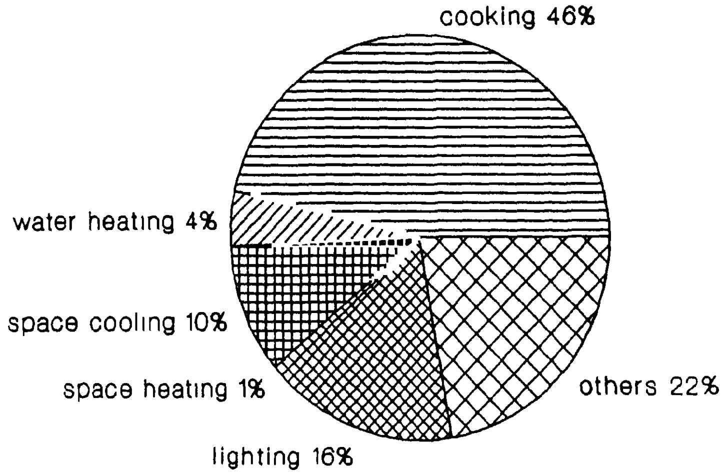
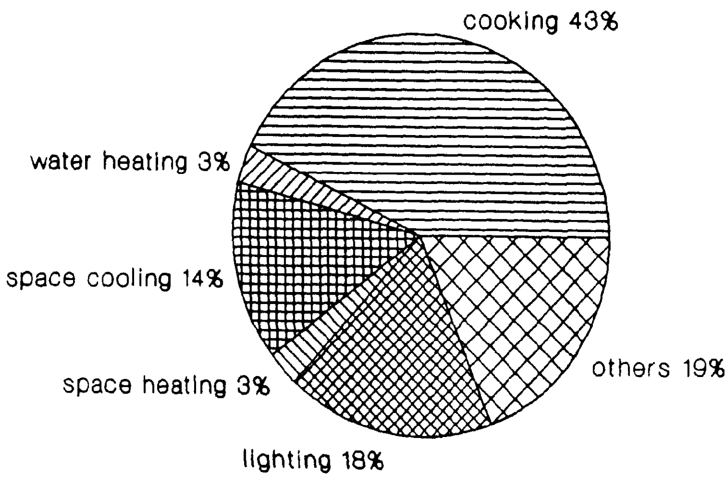


Fig.4.6. Energy share by end-use
Monthly hh. income: over Rs 4500



Finally, in the highest income category, the share of cooking energy was only 43 percent of the total (988,740 kCal per person annually). Consumption of energy for lighting was 18 percent, space cooling 14 percent, water heating 3 percent, space heating 3 percent and "others" 19 percent as shown in Fig. 4 6

4.1 Gross and useful energy consumption

The amount of energy consumed by households depends on the efficiency of energy conversion, which can vary greatly, depending on the kind of fuel and device used The term "useful" energy refers to the amount consumed, net of conversion losses[1] It means that if 'G' is the gross energy consumption of a fuel type in an appliance with, say, efficiency e, then the useful energy, denoted by U corresponding to the same fuel, will be estimated as U = G x e.

Table 4 1 presents the average per capita "gross" and "useful" energy consumption for different end-uses in different income classes

Table 4.1 Annual per-capita energy consumption for various end-uses ('000 kCal)

Income class	Gross energy						
	Cooking	**Water heating**	**Space cooling**	**Space heating**	**Lighting**	**Others**	**Total**
I	315 86	17 09	28 10	1 00	134 56	48 71	545.32
II	318 10	16.70	47 06	3 99	83 64	107 88	577 37
III	379.29	36 39	84 41	6 76	129 26	183 49	819.60
IV	422 86	30 18	142 67	27 58	176 16	189 29	988 74
all together	337 80	35 43	72 77	8 51	124 61	137.30	716 42
Income class	**Useful energy**						
	Cooking	**Water heating**	**Space cooling**	**Space heating**	**Lighting**	**Others**	**Total**
I	164 50	8 70	23 89	0 35	7 96	41 40	246 80
II	171 16	9 20	40 00	1 40	10 42	91 70	323 88
III	219 56	20 10	71 75	2 37	16 22	155 97	485 97
IV	266 63	20 36	121 27	9.65	21 29	160 90	600 10
all together	191 26	19 52	61 86	2.98	13 82	116 70	406 14

Table 4 1 reveals that energy consumption both in terms of gross and useful energy increased with rise in income level Thus, while the lowest income class consumes 164,500 kCal of useful energy for cooking, the highest income category consumes 2,66,630 kCal per capita per annum - nearly 62 percent increase In a report prepared by the Advisory Board on Energy[2], it is reported that in India, the energy consumption of the poorer households is far below the estimated minimum requirement of 620 kCal of useful energy per capita per day (or 226,000 kCal/person/year) in India, which is quite comparable with our survey estimates in Table 4 1 Interestingly, useful energy as a percentage of gross energy consumed for cooking is found to increase, with the lowest income category getting only 52 percent

useful energy output, the second income category getting nearly 54 percent useful energy and a gradual increase from here onwards to about 60% useful energy obtained by the highest income category. This reflects the shift in cooking appliances from kerosene stoves to more efficient LPG and electric stoves for cooking.

Similarly, the trend for water heating is also very clear. The per-capita annual useful energy for water heating went up from nearly 9,200 kCal in the lowest income class to as high as 20,360 kCal in the highest income class - a twofold increase. Here also, useful energy as a percentage of gross energy consumed for water heating is found to increase with the lowest income category, from a little over 50 percent to as high as 67 percent in the highest income category. This again reflects a similar shift from kerosene stoves to more efficient appliances like electric geyser for water heating.

Space cooling and heating requirements are fully met by electricity. For both these end-uses, electricity consumption increased with rise in income. In terms of useful energy, the energy consumption level went up by 5 times for space cooling and by 28 times for space heating between the lowest income and the highest one.

Lighting requirements also increased with increase in income in terms of useful energy. While gross energy consumption was higher for the lowest income household as compared to class II and class III, the useful light output increased with increase in household income. In fact, in the highest income class, the useful energy consumed for lighting is nearly two and a half times more than that of the lowest income class. This is because, besides electricity, the lowest income households also consume some amount of kerosene for meeting their lighting requirement, which is relatively very inefficient. On the other hand, for the other three income classes, viz. II, III and IV, the lighting requirement is met by only electricity.

In the "others" category where only electricity is used, the annual per-capita energy consumption went up nearly 4 times from income class I to income class IV.

Thus Table 4.1 indicates that with increase in income, the total per-capita gross and useful energy consumption increases. Interestingly, total useful energy as a percentage of total gross energy in the domestic sector is found to have increased, with the lowest income category getting only 45 percent useful energy output, the second income category getting nearly 56 percent, and the third and the fourth income category both getting 59 percent useful energy output.

The efficiency values used to convert gross to useful energy is presented in Table 4 2[3].

Table 4.2. Domestic appliance efficiency by end-use

End-uses	Energy source	Appliance	Efficiency
Cooking	LPG	Stove	0.60
	Kerosene	Stove	0.50
	Electricity	Coil heater/cooking range/Oven/Toaster	0.85*
Water heating	LPG	Stove	0.60
	Kerosene	Stove	0.50

Table 4.2 (contd.). Domestic appliance efficiency by end-use

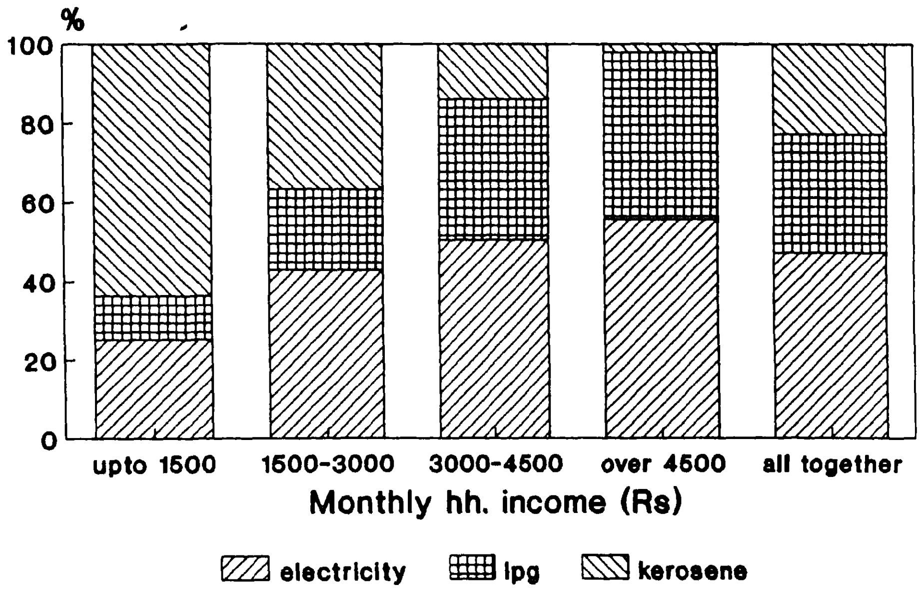
End-uses	Energy source	Appliance	Efficiency
	Electricity	Immersion rod/Geyser/Boiler	0.50*
Space cooling	Electricity	Fan/Desert cooler/air conditioner	0 85*
Space heating	Electricity	Room heater/blower	0.35*
Lighting	Kerosene	Lamps	0.01
	Electricity	Incandescent bulb	0 10
		Fluorescent tube	01 8
Others	Electricity	All other appliances	0 85*

*Personal communication with experts

4.2 Energy mix across income groups

The consumption pattern of electricity, LPG and kerosene across different income groups have been analyzed and presented in Fig 4.7

Fig.4.7. Fuel mix across income groups
all end-uses together



As can be seen from Fig 4 7, LPG and electricity consumption increased as the household income went up Share of electricity to total energy consumption in the domestic sector was about 50 percent Of the remaining half, 30 percent is shared by LPG and 20 percent by kerosene Interestingly, as the income level went up, a steady increase in the share of electricity and LPG was observed. Between the lowest and highest income households, the increase in share of electricity and LPG was 2.8 and 4.2 times respectively. But in the case of kerosene, a reverse trend is

observed. In fact, kerosene share went down from 63 percent in the lowest income households to only 2 percent in the highest income households

4.3 Electricity consumption pattern

4 3.1 Electrical appliances, and their usage

Table 4.3 presents the percentage of households using different types of electrical appliances in different income categories. The type of electrical appliances used in the domestic sector are, for

lighting	incandescent bulbs, fluorescent tubes
water heating	immersion rods, geysers/boilers
space cooling	ceiling fans, pedestal fans, desert coolers, air-conditioners
space heating	room heaters, blowers
cooking and baking	cooking ranges/ovens, toasters, coil heaters
others	irons, washing machines, exhaust fans, refrigerators, TVs (black and white), TVs (colours), booster (water) pumps and mixers/grinders

Interestingly, Table 4.3 shows that for lighting nearly 1 percent of the households were not using any incandescent bulbs. Also, the extent of use of fluorescent tubes increased up to the third income category (from 76 2 percent to 97 2 percent) and in the highest income category, its use went down. By pooling all the data from all the households, it is found that nearly 8 percent of the households were not using any fluorescent tubes. For water heating, more households were using instant geysers than immersion rods. Use of ceiling fans for space cooling have shown a more consistent trend across income category, while the use of desert air coolers increased sharply (from 11.5 percent to 73.3 percent) as income level went up. Air-conditioners were used only by the highest income households. For space heating, room heaters were more popular than hot air blowers. The use of room heaters and blowers went up significantly in the highest income class. Of the three electrical appliances used for cooking and baking, coil heaters were used by all income groups but its use was very insignificant (1.3 percent). The other two - cooking range/oven and toaster, were used mostly in the highest income category

Finally, for all other electrical appliances, it was observed that only 63 percent of the households had refrigerators. Irons were used by 47 percent of the total households. Washing machines, exhaust fans, colour televisions, boosters (water) pumps and mixers/grinders were used by 22, 5, 33, 5, and 28 percent households respectively. Also, the use of these appliances went up significantly as income level increased. However, in the case of black and white televisions, its use increased upto to the second income category and thereafter decreased as people in the higher income groups had shifted to colour television.

Table 4.3. Percentage distribution of households using a specific electrical appliance across different income categories

	Income class				
	I	II	III	IV	All
Lighting					
Incandescent bulb	99.2	98 2	98.8	99.3	98 7
Fluorescent tube	76.2	91 5	97 2	97 0	91 9
Water heating					
Immersion rod	--	5 9	14 6	21 5	10 5
Geyser/boiler	0.8	7 8	20 5	43 7	17 0
Space cooling					
Ceiling fan	83 6	98 2	99 2	99 3	96 4
Pedestal fan	22.1	24 4	14 6	29 6	21 8
Desert cooler	11 5	38 5	64 6	73 3	48 8
Air-conditioner	--	--	--	5 2	0 9
Space heating					
Room heater	1.6	3 0	9 5	23 0	8.3
Blower	--	--	0.8	8 2	1 7
Cooking and Baking					
Cooking range/oven	--	--	0 4	4 4	0 9
Toaster	--	1 9	6 3	25 2	7 0
Coil heater	0 8	0 7	2 0	1 5	1 3
Others					
Iron	10.7	39 3	57.5	74 8	46 9
Washing machine	2.5	12 6	32 7	39 3	22 3
Exhaust fan	--	--	7 1	15 6	5 0
Refrigerator	21.3	51 5	83 9	85 2	63.1
Television (B&W)	65 6	70 0	54 7	37 8	58 8
Television (Colour)	4.9	23.3	42 5	58 5	32.8
Water pump	--	1 9	6 3	11 9	4 7
Mixer/grinder	0 8	14 4	34 7	68 9	28 3

4 3 2 Ownership pattern of electrical appliances and their consumption

To understand the average annual consumption of electricity by different appliances, the wattage of each appliance is multiplied by the time it is used for. The appliance ownership pattern of each household is first analyzed (Table 4 4) It is found that as the household income increased the average ownership of some selected electrical appliances owned per family like, incandescent bulbs, fluorescence tubes, ceiling fans, desert coolers, geysers, room heaters, blowers, etc , went up.

Average ratings of some of these appliances, could not be gathered during the survey Instead data was collected on their size This information was converted into

wattage by using the standard norms given in Annexure 4.1. After analyzing the data, the average wattage of different appliances with plausible ranges is computed and presented in Table 4.5.

Table 4.4. Average number of electrical appliances owned per family and in use across different income classes

	Income class				
	I	**II**	**III**	**IV**	**All**
Lighting					
Incandescent bulb	2 31 (1 11)	3 18 (1 93)	4 59 (1 92)	6.64 (3 59)	4 11 (2 63)
Fluorescent tube	1 56 (0 81)	2 02 (1 19)	2 85 (1 28)	3 68 (1 98)	2 55 (1 53)
Water heating					
Immersion rod	--	1 00 (0)	1 00 (0)	1 03 (0 18)	1 01 (0 11)
Geyser/boiler	1 00 (0)	1 00 (0)	1 00 (0)	1 19 (0 54)	1 08 (0 37)
Space cooling					
Ceiling fan	2 97 (1 04)	3 28 (1 43)	3 88 (1 55)	5 68 (3 06)	4 00 (2 09)
Pedestal fan	1.15 (0 45)	1 03 (0 17)	1 00 (0)	1 23 (0 52)	1 09 (0 34)
Desert cooler	1 00 (0)	1 02 (0 14)	1 09 (0 28)	1 31 (0 61)	1 12 (0 39)
Air-conditioner	--	--	--	1 57 (1 40)	1 57 (1 40)
Space heating					
Room heater	1 00 (0)	1 00 (0)	1 00 (0)	1 06 (0 25)	1 03 (0 17)
Blower	--	--	1 00 (0)	1.09 (0 29)	1 08 (0 27)
Cooking and Baking					
Cooking range/oven	--	--	1 00 (0)	1 17 (0 37)	1 14 (0 35)
Toaster	--	1 00 (0)	1 00 (0)	1 06 (0 24)	1 04 (0 19)
Coil heater	1 00 (0)	1 00 (0)	1 00 (0)	1 00 (0)	1 00 (0)
Others					
Iron	1 00 (0)	1 00 (0)	1 00 (0)	1.03 (0 17)	1 01 (0 09)
Washing machine	1 00 (0)	1 00 (0)	1 00 (0)	1 06 (0 23)	1 02 (0 13)
Exhaust fan	--	--	1 00 (0)	1 05 (0 21)	1 03 (0 16)
Refrigerator	1 00 (0)	1 00 (0)	1 00 (0)	1 05 (0 29)	1 01 (0 14)
Television (B&W)	1 00 (0)	1 03 (0 24)	1 01 (0.08)	1 02 (0 14)	1 02 (0 17)
Television (Colour)	1 00 (0)	1 00 (0)	1 00 (0)	1 05 (0 22)	1 02 (0 12)
Water pump	--	1 00 (0)	1 00 (0)	1 00 (0)	1 00 (0)
Mixer/grinder	1 00 (0)	1 00 (0)	1 00 (0)	1 03 (0 18)	1 01 (0 12)

Note. Figures within parentheses indicate the standard deviation

Table 4.5. Wattage of different appliances

(watt/appliance)

	Income class			
	Average	Std. dev.	Minimum	Maximum
Lighting				
Incandescent bulb	68	23	15	360
Fluorescent tube	40	0	40	40
Water heating				
Immersion rod	1229	293	1000	2000
Geyser/boiler	1520	484	750	2500
Space cooling				
Ceiling fan	60	0 5	60	70
Pedestal fan	48	10	40	60
Desert cooler	188	22	150	300
Air-conditioner	1771	377	1000	2000
Space heating				
Room heater	1277	340	1000	2000
Blower	1231	317	1000	2000
Cooking and Baking				
Cooking range/oven	911	256	750	1600
Toaster	932	296	750	1500
Coil heater	1200	332	1000	2000
Others				
Iron	798	108	750	1500
Washing machine	285	134	125	1000
Exhaust fan	74	6	40	75
Refrigerator	100	4	100	180
Television (B&W)	71	10	60	80
Television (Colour)	75	8	60	80
Water pump	770	249	500	1000
Mixer/grinder	378	62	300	500

Information on the amount of time (in hours) these appliances were used daily - separately for week days and holidays was also collected through survey On multiplying the appliance rating (wattage) with time it was used for, the daily consumption of electricity by each appliance was obtained. As some of the appliances are season specific while others are used throughout the year, the

following norms have been assumed to convert the average electricity consumption norm from daily to yearly basis:

- water heating, space heating and space cooling appliances are used in Delhi for three months except for fans which are used for five months in a year.
- all other appliances are used throughout the year (250 week days and 115 holidays).

Tables 4.6 and 4.7 present annual per capita and per household electricity consumption by different electrical appliances across different income categories.

Table 4.6 Per-capita annual electricity consumption by different electrical appliances across income categories **(in kWh)**

	Income class				
	I	II	III	IV	All
Lighting					
Incandescent bulb	47 53 (39 28)	68 62 (58 54)	103 71 (83 00)	152 62 (120 24)	91 34 (85 77)
Fluorescent tube	26 61 (25 25)	32 69 (26 50)	49 17 (32 10)	54 98 (34 00)	41 64 (31 60)
Water heating					
Immersion rod	--	26 19 (20 21)	18 88 (12 30)	16 52 (15 70)	19 47 (15 72)
Geyser/boiler	8 80 (0)	30 87 (41 79)	16 02 (8 24)	34 67 (70 15)	26 59 (50 63)
Space cooling					
Ceiling fan	32 80 (21 25)	43 23 (33 95)	78 22 (57 72)	124 73 (89 98)	68 03 (63 36)
Pedestal fan	11 22 (14 91)	5 21 (6 10)	3 03 (3 65)	6 50 (7 65)	5 99 (8 54)
Desert cooler	24 23 (14 01)	28 62 (16 84)	31 15 (21 43)	41 98 (24 15)	33 02 (21 55)
Air-conditioner	--	--	--	180 97 (166 97)	180 97 (166 97)
Space heating					
Room heater	70 78 (41 25)	156 62 (133 43)	74 67 (42 80)	99 48 (55 07)	96 47 (70 79)
Blower	--	--	102 16 (45 49)	113 26 (61 61)	111 55 (59 55)
Cooking and Baking					
Cooking range/oven	--	--	11 41 (0)	61 32 (59 05)	54 19 (57 39)
Toaster	--	33 07 (12 48)	38 57 (44 41)	29 31 (22 66)	32 34 (30 37)
Coil heater	365 00 (0)	127 75 (91 25)	146 42 (111 96)	47 22 (13 61)	144 70 (121 58)
Others					
Iron	42 51 (104 27)	19 25 (28 87)	21 10 (30 26)	22 83 (20 11)	21 80 (33 50)
Washing machine	4 80 (1 27)	13 74 (17 53)	13 50 (24 13)	14 73 (21 66)	13 77 (22 03)
Exhaust fan	--	--	11 54 (9 08)	13 48 (9 24)	12 58 (9 22)
Refrigerator	172 85 (74 16)	179 62 (72 55)	195 72 (100 35)	186 46 (71 00)	187 82 (85 78)
Television (B&W)	21 75 (12 47)	21 15 (12 33)	22 35 (11 26)	20 98 (11 08)	21 60 (11 92)
Television (Colour)	17 71 (9 28)	22 03 (10 48)	25 42 (11 57)	25 25 (12 23)	24 35 (11 61)
Water pump	--	84 74 (33 65)	57 43 (25 04)	47 74 (34 77)	56 93 (32 98)
Mixer/grinder	2 03 (0)	15 05 (29 63)	15 04 (29 81)	11 52 (21 91)	13 50 (26 73)

Note Figures within parenthesis indicate the standard deviation

Table 4.7 Per household annual electricity consumption by different electrical appliances across income categories

(in kWh)

	Income class				
	I	II	III	IV	All
Lighting					
Incandescent bulb	214 50 (144 70)	350 96 (292.77)	482 59 (301 01)	796 80 (720.23)	449 89 (430 92)
Fluorescent tube	121 99 (89 73)	164 57 (120 52)	233 20 (128 26)	298 02 (181 46)	207 01 (144 95)
Water heating					
Immersion rod	--	112 06 (62 59)	88 50 (65 50)	101 58 (82 71)	92 72 (72 13)
Geyser/boiler	8 80 (0)	30 87 (41 79)	16 02 (8 24)	34 67 (70 15)	26 59 (50 63)
Space cooling					
Ceiling fan	166 73 (95 62)	219 61 (160 33)	367 99 (222 68)	611 19 (352 76)	331 79 (267 35)
Pedestal fan	11 22 (14.91)	5 21 (6 10)	3 03 (3 65)	6 50 (7 65)	5 99 (8 54)
Desert cooler	24 23 (14 01)	28 62 (18 84)	31 15 (21 43)	41 98 (24 15)	33 02 (21 55)
Air-conditioner	--	--	--	180 97 (166 97)	180 97 (166 97)
Space heating					
Room heater	70 78 (41 25)	156 62 (133 43)	74 67 (42 80)	99 48 (55 07)	96 47 (70 79)
Blower	--	--	102 16 (45 49)	113 26 (61 61)	111 55 (59 55)
Cooking and Baking					
Cooking range/oven	--	--	45 63 (0)	366 35 (355 15)	320 54 (347 43)
Toaster	--	183 60 (81 75)	160 09 (142 79)	141 49 (113 00)	150 73 (120 87)
Coil heater	730 00 (0)	730 00 (365 00)	872 00 (555 48)	283 33 (81 67)	711 67 (481 57)
Others					
Iron	120 49 (202 02)	94 91 (126 85)	102 70 (145 57)	118 20 (115 41)	105 67 (135 42)
Washing machine	37 18 (13 98)	65 95 (72 52)	70 84 (141 08)	90 86 (201 41)	75 43 (152 12)
Exhaust fan	--	--	41 45 (32 65)	54 87 (23 88)	48 68 (29 05)
Refrigerator	876 00 (0)	876 00 (0)	876 00 (0)	935 42 (0)	889 86 (145 05)
Television (B&W)	101 20 (23 80)	104 41 (26 89)	106 40 (28 41)	102 97 (31 84)	104 29 (26 90
Television (Colour)	118 12 (19 71)	113 83 (27 04)	119 02 (23 40)	130 56 (48 21)	121 28 (34 35)
Water pump	--	413 00 (70 84)	356 13 (137 22)	322 64 (367 51)	349 34 (260 97)
Mixer/grinder	12 17 (0)	71 81 (139 38)	70 46 (149 34)	61 69 (122 94)	66.74 (136 76)

Note Figures within parenthesis indicate the standard deviation

It would now be useful to see the share of electricity consumption to the total by different electrical appliances. Table 4.8 presents the electricity consumption share (in percentage) by different appliances across income classes. By clubbing data from all the households, it was found that nearly 30 percent of the total electricity in the domestic sector was consumed by refrigerators This was followed by nearly 23 percent by incandescent bulbs; 17 percent by ceiling fans, 10 percent by fluorescent tubes, 4 percent by desert coolers and the remaining share was consumed by all other appliances together.

Also, the consumption of electricity by different appliances in each income category have shown that:

- In the lowest income category, nearly 29 percent of the total electricity went for incandescent bulbs, followed by refrigerators (23 percent); ceiling fans (17 percent); fluorescent tubes (13 percent); televisions (black and white) (9 percent); and the rest is shared by all other appliances

In the other three higher income classes (II, III and IV), a similar trend was observed for the share of electricity by major appliances in descending order of consumption viz refrigerators, incandescent bulbs, ceiling fans, fluorescent tubes, televisions. All these appliances together consumed as high as 90 percent of the total electricity

Table 4.8. Electricity consumption share (percent) by different electrical appliances across income categories

	Income class				
	I	**II**	**III**	**IV**	**All**
Lighting					
Incandescent bulb	29 29	23.42	21.30	23 22	22 90
Fluorescent tube	12.60	10.40	9 94	8 18	9 72
Water heating					
Immersion rod	0 00	0 54	0 57	0 54	0 52
Geyser/boiler	0 04	0 83	0 68	2 32	1 15
Space cooling					
Ceiling fan	17 04	14.75	16 13	18 98	16.66
Pedestal fan	1 54	0 44	0 09	0 30	0 33
Desert cooler	1 73	3.83	4.18	4 72	4 09
Air-conditioner	0 00	0.00	0.00	1 44	0 46
Space heating					
Room heater	0 72	1 61	1 47	3 50	2 04
Blower	0 00	0 00	0 17	1 41	0.47
Cooking and Baking					
Cooking range/oven	0 00	0.00	0 01	0 42	0 12
Toaster	0 00	0 21	0 50	1 13	0 58
Coil heater	1 86	0 33	0 60	0 11	0 47
Others					
Iron	2 81	2 63	2 52	2 62	2.59
Washing machine	0 07	0 60	0.92	0 89	0 77
Exhaust fan	0 00	0 00	0 17	0 32	0 16
Refrigerator	22 88	32.16	34 12	24.35	30.11
Television (B&W)	8 86	5 15	2.54	1.21	3 22
Television (Colour)	0 54	1.79	2 25	2.26	2 03
Water pump	0 00	0.55	0 75	0 87	0.68
Mixer/grinder	0 01	0 76	1 08	1.22	0.97

4 3.3 *Electricity consumption by end-use*

Table 4.9 presents the total electricity consumption for different end-uses on a per capita basis across the four income categories. It can be seen from Table 4.9 that the annual per-capita electricity consumption increased fourfold from the lowest to the highest income category. Annual per capita electricity consumption in the lowest income households was 161 kWh; in class II it was 288 kWh; class III 481 kWh; and in the highest income category, the consumption was around 652 kWh.

Table 4.9. Per capita annual electricity consumption and its distribution over various end-uses across different income categories

	Income class				
	I	**II**	**III**	**IV**	**All**
Cooking	2.99	1 56	5 36	10.81	4 62
Water heating	0.07	3.95	6.03	18.70	6 57
Space cooling	32.68	54.73	98 16	165 90	84 62
Space heating	1.16	4.64	7.86	32.07	9.89
Lighting	67.43	97.25	150.30	204.85	128.45
Others	56.63	125.45	213.36	220.10	159 65
Total	160 96	287.58	481.07	652 43	393 80

All the appliances clubbed under "others" category had the largest share in electricity consumption (41 percent). This was followed by lighting (33 percent), space cooling (21 percent), space heating (3 percent), water heating (1 percent) and the rest was for cooking

While analyzing the same data for different income groups it was found that in the lowest income class, lighting consumed the maximum electricity (42%), followed by "others" (35%); space cooling (20%); cooking (2%); space heating (0.6%) and water heating (0.4%). However, in the case of class II and class III, the share of electricity consumption was highest for others, followed by (in descending order of magnitude) lighting, space cooling, space cooling, space heating, water heating and then cooking. But in the highest income group, the trend had slightly altered and it was found that nearly 34% of total electricity was consumed by appliances in "others" category. This was followed by lighting (31%); space cooling (25%), space cooling (25%); space heating (5%); water heating (3%); and cooking (2%).

4.4 Kerosene consumption pattern by end-use

Kerosene is primarily a cooking fuel and to some extent is also used for water heating. The survey data indicates that kerosene was also used for lighting in households with income less than Rs.1500 per month, besides being used for cooking and water heating. The dependence on kerosene in the case of lower income households was very high. Nearly 92% of the households in this category were using kerosene for meeting their energy demand for cooking, water heating and/or lighting

(Table 4.10). But with rise in income level, the percentage of households using kerosene decreased. For income classes II, III and IV, the percentage of households using kerosene went down to 86%, 38% and 9%, respectively. Table 4.10 also provides the annual per capita kerosene consumption in each income categories It was observed that consumption of kerosene declined steadily (by 60%) from 43.73 litre to 26.43 litre per capita annually with the rise in income level. Typically, in Delhi, average per-capita kerosene consumption by user population (54% of the total sample) was 34 92 litre per person annually. Table 4 10 also reveals that kerosene consumption in winter months was nearly 20% more than that of summer. This increase was due to an increase in demand for hot water in winter months, coupled with higher food intake.

Table 4.10. Per-capita consumption of kerosene across different income categories

Income class	Kerosene (litre)			% of households using kerosene
	Monthly		Annual	
	Summer	Winter		
I	3.33 (2.95)	3 96 (3 49)	43 73	92 35
II	2 10 (2.63)	2.67 (3 20)	28 61	86 32
III	2.58 (2.34)	3 15 (2.88)	34 47	38 45
IV	2.05 (1 68)	2.35 (1.63)	26.43	9 26
All	2 64 (2.73)	3.18 (3.22)	34 92	54 49

4 4 1 Kerosene consumption by end-use

The distribution of kerosene consumption for different end-uses is presented in Table 4 11. Nearly 76% of the total kerosene was consumed for cooking, 16% for water hearting and 8% for lighting. Further, on examining these shares across different income groups it was observed that none of the households, with income more than Rs 1500, used kerosene for lighting. In fact, households with income less than Rs.800 per month consumed some amount of kerosene to meet their lighting requirement In the lowest income group, the share of kerosene for cooking was 73%, followed by lighting (22%) and the remaining (5%) for water heating. On the other hand, in the three other higher income classes with rise in income level, the share of kerosene for cooking decreased from nearly 94% to 67% while the remaining share went for water heating.

Table 4.11. Per-capita annual kerosene consumption and its distribution over various end-uses across different income categories

(in litres)

Income class	**Cooking**	**Water heating**	**Lighting**	**Total**
I	29.66	1.82	8.90	40.38
II	23.30	1.40	--	24.70
III	10.65	2.56	--	13.22
IV	1.63	0.81	--	2.45
All	14.43	2 96	1.64	19.03

4 4 2 Time distribution of kerosene use

Table 4 12 presents the total time kerosene was used daily for cooking, water heating and lighting

A household in Delhi was using about 3.7 hours daily for cooking purposes using kerosene. Time spent for lighting was nearly 3 hours and for water heating 1 2 hours. An income-wise break-up of time spent on various end-uses using kerosene can also be studied from Table 4 12.

Table 4.12 Time spent (in hours) daily per household using kerosene (hours/day)

Income class	**Kerosene**		
	Cooking	**Water heating**	**Lighting**
I	4.13 (1 63)	1 31 (0 64)	3.00 (0.75)
II	3.35 (1 49)	1 02 (0 58)	--
III	2.26 (1 02)	0.85 (0.62)	--
IV	2.05 (0 50)	0 88 (0.57)	--
All	3 67 (1.65)	1.17 (0.64)	3.00 (0.75)

Note: Figures within parentheses indicate the standard deviation

4.5 LPG consumption pattern

Unlike electricity and kerosene, the average per-capita annual consumption of LPG (user households) did not show any steady increase or decrease across income groups (Table 4 13). Only 13% of the households having an income less than Rs 1500 consumed LPG The percentage share of LPG user households went up from nearly 24% in class II to 87% to class IV. This indicates that though there was not much of variation in consumption of LPG among user households, the percentage of households used LPG differs considerably across income groups. It is estimated that annual LPG consumption was 44.61 kg on a per-capita basis There was a gradual

increase from 41.57 kg in class I households to about 45.39 kg in class IV households in terms of per capita annual LPG consumption. Moreover, there was hardly any variation in LPG consumption in income groups II, III and IV which was nearly 45 kg per person per annum. As in the case of kerosene, there was also an overall increase in the LPG consumption norm in the winter months as compared to summer months by about 12%. The reason for the increase was the same, as mentioned in the case of kerosene i.e. increase in demand for hot water in winter months coupled with higher food intake.

Table 4.13. Per-capita consumption of LPG across different income categories

Income class	LPG (kg)			% of households using LPG
	Monthly		Annual	
	Summer	Winter		
I	3 25 (1.19)	3.68 (1.44)	41 57	13 41
II	3.50 (1 32)	3.95 (1.55)	44 68	24.39
III	3.51 (1.13)	3 93 (1.36)	44 61	60 66
IV	3.61 (1.38	3 95 (1.60)	45 39	87.03
All	3.51 (1.30)	3 92 (1.53)	44 61	44.44

Note· Figures within parentheses indicate the standard deviation.

4 5 1 LPG consumption by end-use

The distribution of per capita LPG consumption for cooking and water heating is presented in Table 4 14. Here, the per-capita LPG consumption is calculated by taking each households irrespective of whether they were using this fuel or not Due to large percentage of households using LPG in the highest income class it was found that the consumption of LPG went up by nearly 7 times with increase in income Also, LPG was mainly consumed (as high as 98%) for cooking only and the remaining 2% was for water heating Interestingly, the share of LPG consumed for cooking and water heating remained almost constant with rise in income level.

Table 4.14. Per capita annual LPG consumption and its distribution over various end-uses across different income categories

(in kg)

Income Class	Cooking	Water heating	Total
I	5 44	0 13	5.57
II	10.78	0.12	10.90
III	26 21	0.85	27.06
IV	38 84	0.66	39.50
All	19.42	0 40	19 82

4 5.2 Time distribution of LPG use

Table 4.15 presents LPG used in hours for cooking and water heating in different income classes.

Nearly 3 37 hours was spent daily on cooking, and water heating took 0.81 hours using LPG. Table 4.15 also shows the rate at which LPG used (in hours increased with rise in income

Table 4.15. Time spent daily per household using LPG

(hours/day)

Income class	LPG	
	Cooking	Water heating
I	2.98 (1.16)	0.80 (0.24)
II	3 12 (1.19)	0.73 (0.36)
III	3.51 (1 38)	0.98 (0.82)
IV	3 61 (1.42)	0 75 (0.33)
All	3 37 (1 34)	0 81 (0 51)

Note: Figures within parentheses indicate the standard deviation

4.6 Changes in energy use pattern by end-use

4.6.1 Cooking

Tables 4 16 and 4.17 give the percentage distribution of fuels consumed for cooking in different income classes during two different years 1989 and 1985. The changes in the pattern of fuel use for cooking is also shown through stacked bars in Figures 4.8 and 4.9 respectively.

Table 4.16. Percentage distribution of households consuming various fuels for cooking during 1989

Income Class	Only			L+K	L+E	K+E	L+K+E	All together
	L	K	E					
I	33.78	43.24	--	8.78	10 81	0.69	2 70	100
II	54 58	8.17	0.33	5.88	26.80	1.96	2 28	100
III	50.68	6.08	--	3.38	38 51	--	1 35	100
IV	50.52	2.44	0 70	1.05	41.11	1.05	3 13	100
All	49.16	11.81	0 34	4.39	30 71	1 12	2 47	100

L LPG, K: Kerosene; E: Electricity

Table 4.17. Percentage distribution of households consuming various fuels for

Income Class	**Only**			**L+K**	**L+E**	**K+E**	**L+K+E**	**C+F+K +D**	**All together**
	L	**K**	**E**						
I	25.68	50.68	--	6 76	6.08	3.38	2.70	4.72	100
II	42.81	17.65	0.98	5.88	15.03	2.94	5.56	9 15	100
III	47.97	8.78	0.68	3 38	26.35	2.70	4.05	6 09	100
IV	50.17	4 53	1.05	1.39	34.84	1 74	3 14	3.14	100
All	43.19	17.44	0.79	4 16	21.82	2.59	4.05	5 96	100

L. LPG; K: Kerosene; E: Electricity; C· Coke; F: Firewood, and D Dung cake

Fig.4.8. Distribution of hhs. consumed various fuels for cooking in 1989

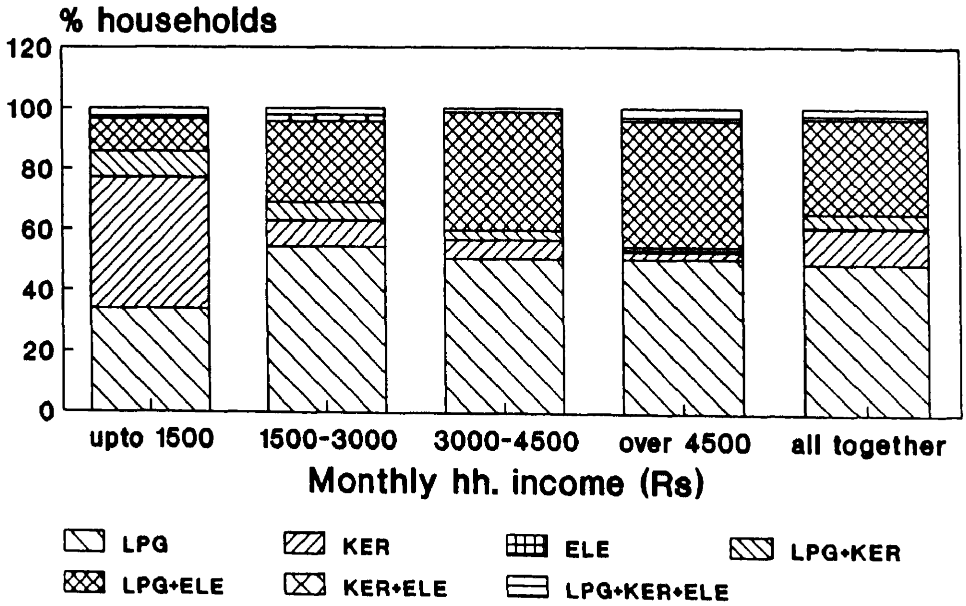
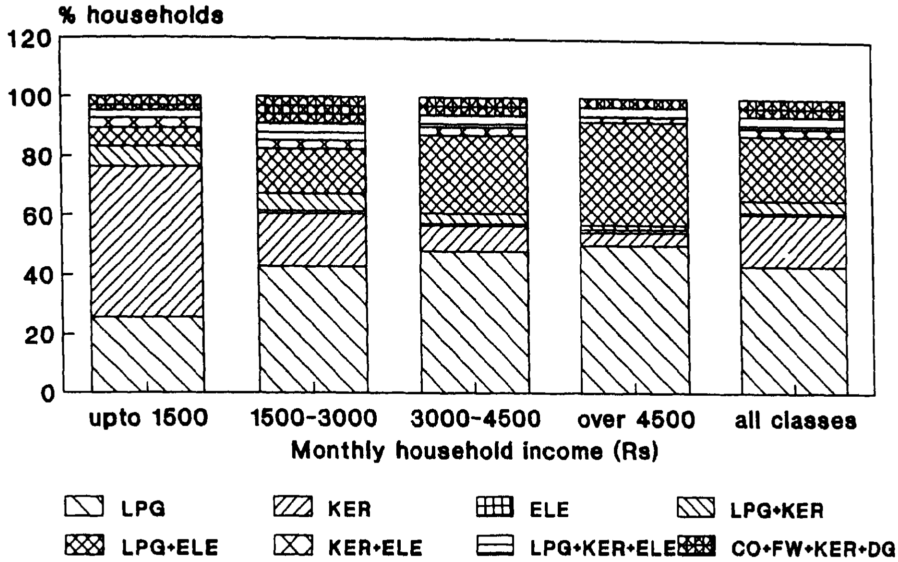


Fig.4.9. Distribution of hhs. consumed various fuels for cooking in 1985



LPG was largely used for cooking purposes by all income classes except the lowest, where kerosene was found to be the dominant fuel. Nearly 14% more households were using LPG for cooking with respect to five years ago. Also from 1985 to 1989 the percentage of households using LPG for cooking had increased, particularly in the lower income groups. On the other hand, the number of households using kerosene went down in 1989 by nearly 48%. As income increased, there was a rapid fall in kerosene use from as high as 85% to nearly 46%. It can also be observed that in 1989 there were no households consuming fuels like soft coke, firewood and dung-cake for cooking, while their share together with kerosene, was about 6% during 1985. The use of LPG and kerosene and/or LPG and electricity had increased, while the use of kerosene had declined.

4 6 2 Water heating

The percentage distribution of various fuels consumed for water heating across different income classes is presented for two different periods 1989 and 1985 in Tables 4.18 and 4.19 respectively (see also Figures 4.10 and 4.11).

Table 4.18. Percentage distribution of households consuming various fuels for water heating during 1989

Income Class	Only			L+K	L+E	K+E	L+K+E	All together
	L	K	E					
I	11 49	52.70	17.57	5.41	2.03	1.35	9 45	100
II	17.32	18.63	44.77	2.94	6.21	5.23	4.90	100
III	14.86	11.49	62.16	1.35	4.05	2.03	4.06	100
IV	6.97	4.88	72.47	1.74	5.57	3.48	4.89	100
All	12.60	18.67	52.08	2.70	4.95	3.49	5.51	100

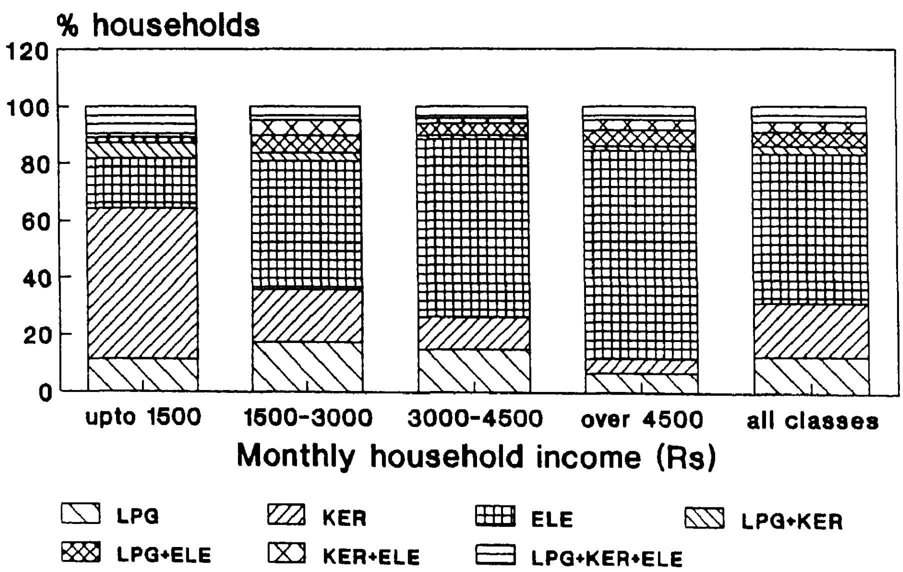
L· LPG; K: Kerosene; E: Electricity.

Table 4.19 Percentage distribution of households consuming various fuels for water heating during 1985

Income Class	Only			L+K	L+E	K+E	L+K+E	C+F+K+D	All together
	L	K	E						
I	10 81	50 68	14 19	3 38	0 68	6 08	3 37	10 81	100
II	12 09	20 92	37 58	2 61	3 59	8 17	6 87	8 17	100
III	13 51	13.51	54 05	0 68	2 70	5 41	7 44	2 70	100
IV	6 27	6.27	65 85	1 74	4 53	3 14	10 81	1 39	100
All	10 46	19 91	45 56	2 14	3 26	5 74	7 42	5 51	100

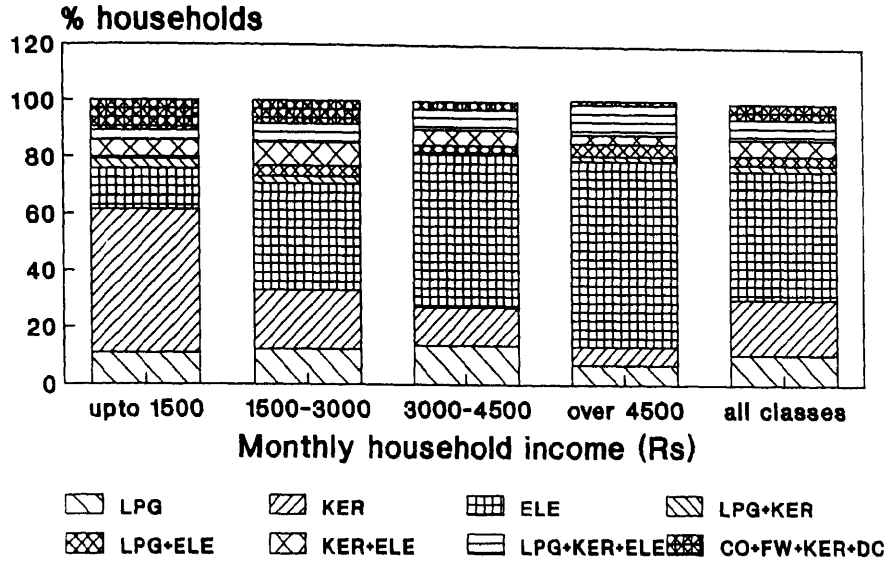
L LPG, K Kerosene, E Electricity, C Coke, F Firewood, and D Dung cake

Fig.4.10. Distribution of hhs. consumed various fuels for water heating in 1989



Electricity by and large was the major fuel used for water heating except in the lowest income class where kerosene was the dominant fuel. it can be observed that in 1989, 14% and 20% more households had shifted towards use of electricity and LPG respectively as compared to five years earlier but the kerosene share had gone down by nearly 7% Also, there was a steady increase in the use of electricity for water heating with increase in income, and the trend was exactly the reverse in the case of kerosene Survey data confirms that five years ago, kerosene, soft coke, firewood and dung cake were also being used for water heating its share was about 5 5% While analyzing the same data across income groups, it reveals that with rise in income, the total share of these fuels went down (from 10.8% to 1.4%) by nearly 8 times During 1989, no households in the urban area of Delhi were using coke or firewood for water heating.

Fig.4.11. Distribution of hhs. consumed various fuels for water heating in 1985



4 6.3 Lighting

Electricity was totally used for meeting the lighting demand in 1989 in income classes II, III, IV (Table 4 20 and Figures 4.12 and 4.13). But in the lowest income class nearly 27% of households met a part of their lighting demand by kerosene.

During 1985, all households were using kerosene along with electricity for lighting though its share in the higher income groups II and IV was very little.

Table 4.20. Percentage distribution of households using different fuels for lighting

Income class	1989/90				1985/86			
	Only K	Only E	Both K+E	All together	Only K	Only E	Both K+E	All together
I	27.03	69.59	3 38	100	33.11	56.08	10 81	100
II	--	100 00	--	100	10 13	84.31	5.56	100
III	--	100 00	--	100	2 70	92 57	4.73	100
IV	--	100.00	--	100	2.44	95.12	2.44	100
All	4.50	94.03	1 47	100	10 24	84.48	5.28	100

K: Kerosene; E: Electricity

Fig.4.12. Distribution of hhs. consumed various fuels for lighting in 1989

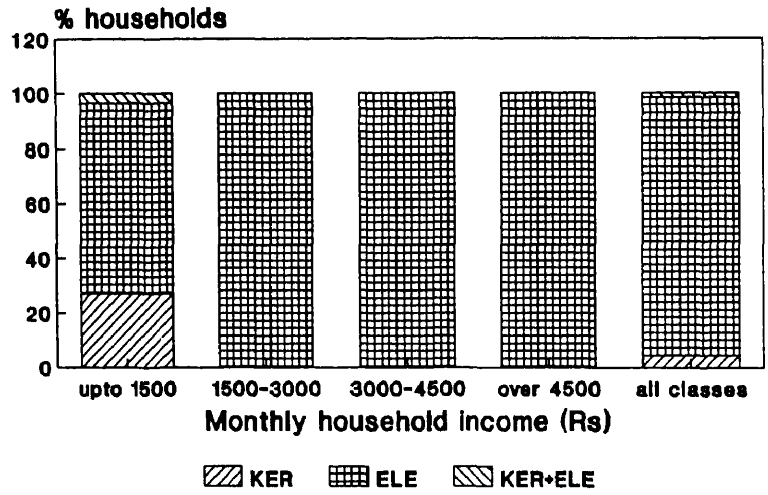
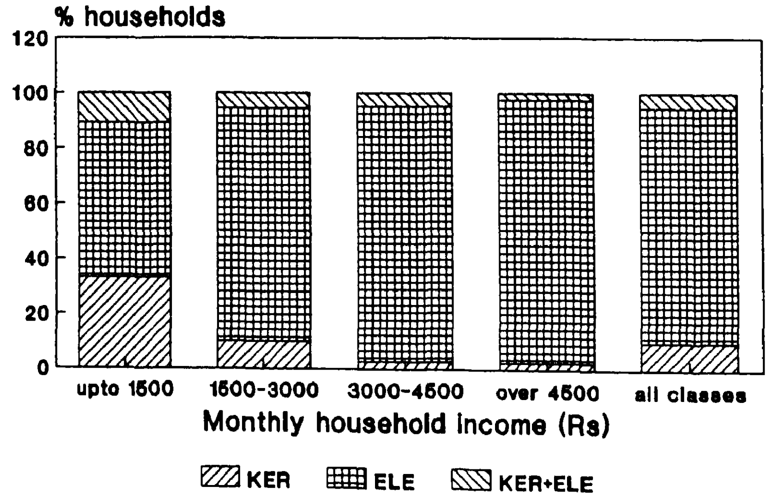


Fig.4.13. Distribution of hhs. consumed various fuels for lighting in 1985



4.7 Total energy demand and projection

4.7 1 Energy Supply

Data on energy supply figures were collected from secondary sources like the sales estimates of LPG, kerosene and electricity. Total electricity sales figures in Delhi are collected from various documents published from the Central Electricity Authority, whereas, data for petroleum products are obtained from documents published by the Petroleum Ministry[4].

The time series data for the total sales of LPG, kerosene and electricity in Delhi are presented in Table 4.21. Electricity supply share in the domestic sector alone was 41% during 1991-92 (Table 4.21). Electricity consumption during the period 1980-81 to 1990-91 has gone up by an average annual growth rate of 11%. The electricity sold in the domestic sector alone during the same period has gone up

from 0.7 tWh to 2.3 tWh with annual growth rate around 11.7% (Table 4.21). The share of electricity in the domestic sector has gone up steadily from around 32% to 41% during the period 1975-76 to 1991-92.

Table 4.21 Consumption of energy in Delhi

Year	LPG	Kerosene	Electricity		
			Total	Domestic	Domestic share
	10^3t	10^3t	gWh	gWh	%
1975-76	33.80	75 00	1447 00	469 00	32 41
1976-77	38 20	77 70	1608 00	514 00	31 97
1977-78	42 10	91 35	1693 00	522 00	30 83
1978-79	46 00	105 00	1893 00	594 00	31 38
1979-80	47 00	103 00	2083 00	660 00	31 69
1980-81	47 00	157 00	2308 00	765 00	33 15
1981-82	55 00	147 00	2505 00	833 00	33 25
1982-83	66 00	147 00	2720 00	931 00	34 23
1983-84	76 00	157 00	2976 00	1038 00	34 88
1984-85	89 00	165.00	3377 00	1211 00	35 86
1985-86	114 00	177 00	3757.00	1379 00	36 70
1986-87	128 00	189 00	4037 00	1385 00	34 31
1987-88	144 00	200 00	4482 00	1483 00	33 09
1988-89	168 00	209 00	4820 00	1635 00	33 92
1989-90	190 00	218.00	5600 00	1915 00	34 20
1990-91	205 00	237 00	6415 00	2316 00	36 10
1991-92	220 00	na	7061 00	2900 00	41 07
1992-93	239 00	na	na	na	na
2000-01(estimated)	607 89	337.94	16305 54	6622 51	40 62
Annual growth rate (%) 1975-76 to 1985-96	12 93	8 97	10 01	11 39	-
Annual growth rate (%) 1980-81 to 1990-91	15 87	4 20	10 76	11 71	-

During the period 1975-76 to 1990-91, LPG sales has gone up from 34 thousand tonnes to 205 thousands tonnes (annual growth rate 16%)· kerosene sales, on the other hand have also gone up from 75 to 237 thousand tonnes (annual growth rate of 4%) as given in Table 4.21.

To extrapolate the future supply potential of electricity, LPG and kerosene in Delhi during 2000-01, the following time trend equations have been used. Estimates of energy supply potential for 2000-01 are presented in Table 4 21.

(a) LPG supply:

$$\text{Log } Y_t = 3\ 29 + 0\ 12\ t \qquad R^2 = 0\ 98$$
$$(29\ 90)^{a}$$

(b) Kerosene supply.

$$Y_t = 63\ 83 + 10\ 54\ t \qquad R^2 = 0\ 97$$
$$(20.09)$$

(c) Total electricity supply·

$$\text{Log } Y_t = 7\ 15 + 0\ 098\ t \qquad R^2 = 0\ 99$$
$$(72\ 07)$$

(d) Domestic electricity supply.

$$\text{Log } Y_t = 5\ 98 + 0\ 108\ t \qquad R^2 = 0\ 99$$
$$(34.63)$$

where,

Y = Type of energy source

t = (year+1) - 1975/76

4.7.2 Energy demand in 1989 and 2001

Using section 3 1 5, total demand of LPG, kerosene and electricity are estimated across different income groups for two different periods 1989 and 2001 and are presented in Tables 4 22 and 4.23 respectively

Table 4.22 Total energy demand in the domestic sector of Delhi in 1989

Income class	Annual per-capita consumption in 1989			Popn. distn. in 1989	Popn. in Delhi in 1989	Annual total energy demand in 1989			
	LPG	Ker.	Elec.			LPG	Ker	Elec.	Total
	kg	kg	kWh	%	million	'000t	'000t	gWh	10^9kCal
I	5 57	32 71	160 96	22	1 36	7 58	44 48	218 91	742
II	10 90	20 01	287 58	40	2 47	26 92	49 42	710 32	1425
III	27 06	10 71	481 07	36	2 22	60 07	23 77	1067 98	1819
IV	39 50	1 98	652 43	2	0 12	4 74	0 24	78 29	121
All together				100	6 17	99 31	117 91	2075 50	4107

[a] t-statistic with 14 degrees of freedom.

Table 4.23 Total energy demand in the domestic sector of Delhi in 2001

Income class	Annual per-capita consumption in 1989			Popn. distn.	Popn.in Delhi	Annual total energy demand in 2001			
	LPG	Ker.	Elec.			LPG	Ker.	Elec.	Total
	kg	kg	kWh	%	million	'000t	'000t	gWh	10^9 kCal
I	5 57	32.71	160 96	17	1 70	9 48	55 66	273 91	928
II	10 90	20 01	287 58	38	3 80	41 46	76 10	1093 90	2195
III	27 06	10 71	481 07	38	3 80	102.93	40 73	1829 89	3117
IV	39 50	1 98	652 43	7	0 70	27 68	1 39	457 16	707
All together				100	10 01	181 55	173 88	3654 85	6947

Total supply of LPG, kerosene and electricity in different sectors of Delhi during 1989 and 2001 are estimated to be 8891 and 17964 billion kCal, respectively (Tables 4 21 and 3 10). However, the total demand of these three fuels in the domestic sector only is estimated as 4107 and 6947 billion kCal, respectively This indicates the share of these fuels (of the total sales) in the domestic sector alone is around 46% and 39% respectively.

It is estimated that with respect to the total sales of LPG, kerosene and electricity in Delhi during 1989, their share in the domestic sector alone is around 53%, 56% and 39% respectively On the other hand, during 2001, the corresponding share would change to 78%, 58% and 36% respectively. The total estimated electricity demand in the domestic sector is 2 1 tWh which is just the same as the total electricity sold in Delhi during 1989. During 2001 the projected electricity demand in the domestic sector is 3.7 tWh which is also compatible with the projected electricity sales

But the domestic consumption share of LPG and kerosene in 1989 seems to be an underestimated figure This is because the total demand is estimated with respect to only 71% of the total population who are residing in permanent settlements with electricity connection[5] The remaining 29% are residing in either slums or in newly constructed resettlement areas where electricity is not available. This percentage of the population mainly uses traditional fuels like firewood, soft coke and dung-cake along with kerosene and LPG. Besides this, LPG and kerosene are being widely used in services and in the commercial sector Some amount of LPG is also consumed by the industries located in and around Delhi.

References

Chapter 4

1 Sathaye, J and S Meyers 1985. "Energy use in cities of the developing countries". Annual Review of Energy 10·109-133, Annual Reviews Inc California, USA

2 GOI. 1985. "Towards a perspective on energy demand and supply", Advisory Board on Energy, New Delhi.

3 Sharma, R and R Bhatia 1986. "India Meeting basic energy needs of the poor - Volume II" Regional energy development programme (RAS/84/001), energy pricing strategies, UNDP, ESCAP, ILO, ARTEP, New Delhi, October

4 Government of India (GOI) several issues. (i) For petroleum "Indian Petroleum& Natural gas Statistics", Economics and Statistics Division, Ministry of Petroleum and Natural Gas, New Delhi. (ii) for electricity "Public Electric Supply - All India Statistics", Department of Power, New Delhi

5 Delhi Electric Supply Undertaking 1990 "Electricity statistics 1986/87 to 1988/89", Municipal Corporation of Delhi, New Delhi, pp.7

Chapter 5

Energy demand in the transport sector

With increasing urbanization and rapid growth of our cities, the transport demand is increasing and is characterized by increasing trip lengths and traffic densities, thereby increasing the energy used for population of vehicles. The pattern of transportation in our cities is also characterized by increasing usage of motorized modes With increase in income levels, inadequate provision of public transport services, limitless expansion of our cities, and minimal importance given to non-motorized vehicles, the private vehicle population has grown by leaps and bounds. However, the extent of usage of motorized modes and their mix are different and generally dependent on the factors such as topography and the transport link structure, land-use and density pattern among others. All these factors have an effect on the quantum of commercial energy consumption by the urban transportation system.

Delhi has registered the largest vehicle population (1.92 million in 1991) and is more than the total number of vehicles in Bombay, Calcutta and Madras taken together. The various surveys conducted in Delhi (Maunder 1982, 1983, 1984)[1,2,3] have shown that residential location and to a lesser extent income differences have an important effect both on the relative levels of travel demand and the choice of mode used for travelling. In order to get an insight into the location and income effect on travel characteristics such as trip rate, trip length, modal choice, etc , three different cluster residential settlements in different locations of Delhi were chosen with varying distances from the CBD, Connaught Place. The three locations were Paharganj (PHG), R K Puram (RKP) and Janak Puri (JKP) which are at increasing distance from the CBD.

This chapter analyzes TERI survey data to examine travel characteristics with respect to locational differences of settlements and household income. Demand of petrol and diesel for passenger transportation in Delhi is estimated for the two years 1991 and 2001. Supply potential of these two fuels are projected 2001 by analyzing the time trend of fuel sold in Delhi. The estimated fuel demand is compared against available supply figures.

5.1 Growth of vehicles

The growth of motor vehicles has been significant in Delhi and is given in Table 5 1 Besides the registered motor vehicles, presently there are estimated to be over 11 lakh bicycles and 13000 slow moving vehicles in Delhi The annual growth rate of motor vehicles was about 12% between the last two decades (1971-91). The two wheelers have registered a maximum growth of about 13% per annum. The rate of growth of cars/jeeps was 10%. Public transport buses grew at the rate of 9%. Intermediate Public Transport (IPT) vehicles like taxis and auto rickshaws have registered a growth rate of 5% and 9% respectively between 1971 and 1991.

Table 5 1 Growth and composition of vehicles in Delhi (1970-87) (in thousands)

Vehicle type							Annual growth rate in percent	
	1986	1987	1988	1989	1990	1991	1971-91	1986-91
Cars/Jeeps	202905	241851	279708	332761	383610	427743	10 18	16 09
Motor cycles/ Scooters	746619	867908	978698	1082802	1191186	1294066	13 16	11 63
Auto rickshaws	40713	45546	51700	57761	62007	65829	9 45	10 09
Taxis	8772	8919	9094	9422	10026	10426	4 77	3 52
Buses	14617	15363	16319	17481	18651	19671	9 39	6 12
Goods vehicles	61860	71168	80412	89568	99078	106052	10 18	11 38
Total	1075486	1250755	1415931	1589795	1764558	1923787	11 87	12 33

Table 5 2 gives the estimated number of registered vehicles in Delhi during 2001. A time-trend analysis has been carried out to estimate the growth of different types of vehicles. Data from Table 5 1 has been used to obtain the following time trend equations for projection proposes.

$$y_t = a\, e^{bt}$$

$$\log Y_t = \log a + bt$$

where,
y_t = number of vehicles in time t
t = (year + 1) - 1971
a = constant coefficient
b = coefficient of time t
Using above equation for different types of vehicles, the following linear relationships are obtained. For

Cars/jeeps,

$$Log\ Y_t = 10.88 + \underset{(14.27)}{0.946\,t}; \quad 0.98$$

Scooters/Motorcycles,

$$Log\ Y_t = 11.49 + \underset{(52.64)}{0.1260\,t}; \quad R^2 = 0.99$$

Autorickshaw,

$$Log\ Y_t = 9\ 19 + \underset{(54.03)}{0.0915\,t}; \quad R^2 = 0.99$$

Taxi,

$$Log\ Y_t = 8.28 + \underset{(29.86)}{0.0468\,t}; \qquad R^2 = 0.99$$

Goods,

$$Log\ Y_t = 9.52 + \underset{(53.99)}{0.0977\,t}; \qquad R^2 = 0.99$$

Bus,

$$Log\ Y_t = 8.03 + \underset{(25.64)}{0.0919\,t}; \qquad R^2 = 0.99$$

Table 5.2. Projected number and composition of motor vehicles in Delhi during 2001

Vehicle type	Number of vehicles	% composition
Cars/Jeeps	992156	15 57
Motor cycles/Scooters	4861152	76 28
Auto rickshaws	167022	2 62
Taxis	16877	0.26
Buses	53142	0 83
Goods vehicles	282767	4 44
Total	6373116	100

5.1 1. Vehicle composition

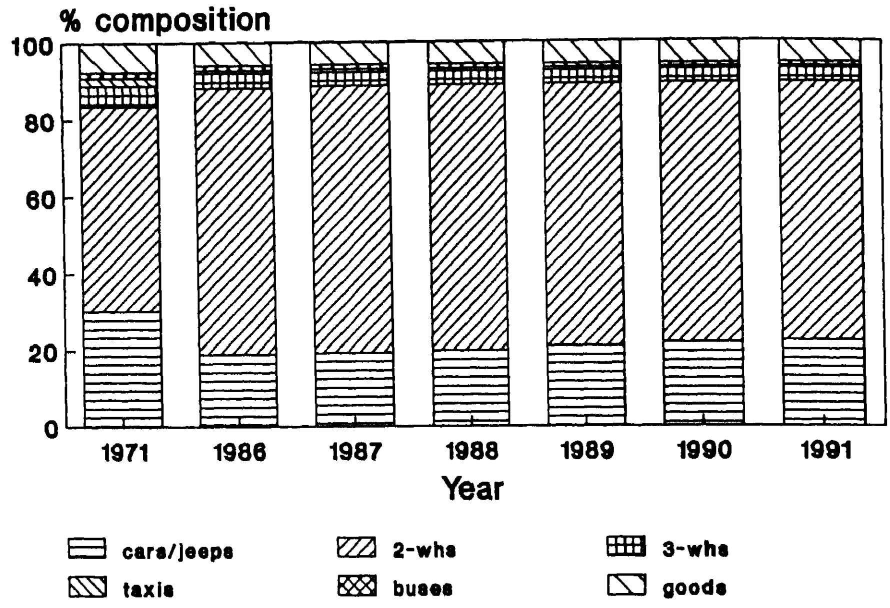
There has been a drastic change in vehicle composition in Delhi in the last two decades Figure 5.1 shows the change in vehicles mix from 1971 to 1991 The two wheelers have become the most popular mode of personal transport and their number is rising Of the total vehicles in 1971, nearly 53% were two-wheelers which went up to 67% in 1991. However, the change in vehicle mix is gradual between 1986 and 1991. Figure 5.1 clearly shows that the percentage share of two-wheelers has increased while the share of all other modes of transport has decreased.

Vehicle ownership per thousand population shows that the two-wheelers have increased by more than three and a half times from 1973 to 1989, while during the same period cars and jeeps have gone up by nearly two times (Table 5 3).

Table 5.3 Estimated personalized vehicle growth per 1000 persons - Delhi

Vehicle type	Vehicle per 1000 population				
	1973	**1977**	**1981**	**1985**	**1989**
Cars, jeeps	17	19	22	22	32
Scooter, motor cycles	35	50	64	81	128

Fig. 5.1. Change in vehicle composition



5.2 Travel pattern

To study the travel pattern and the effect of locations on the mobility pattern, information on travel characteristics was obtained through a household survey in three localities of Delhi, i.e., Paharganj, R K Puram, Janakpuri. Socio-economic data together with data on household and per capita trip rates were collected. Data was also collected on modal choice, distance and time spent in travelling for the various regular trips undertaken daily by each household member. In addition to this, data was collected from secondary sources on growth of vehicles in Delhi, vehicle utilization, efficiency, occupancy level, etc. to augment the primary data.

5.2.1 Modes of transport under operation

The predominant private modes under operation in all the three localities are: two wheelers, cars and bicycles. Public transport services comprise conventional stage buses operated by the Delhi Transport Corporation (DTC), taxis, cycle-rickshaws, auto-rickshaws and privately owned and operated charter buses. The DTC provides a network of bus services to all the three localities under study. Charter buses are contracted by groups of local residents to provide services to import locations mainly around the Connaught Place (CBD) area. Computers tend to use them extensively as they provide a guaranteed seat and are not overcrowded. Fares for chartered buses are significantly higher than DTC buses but services level and comfort are far superior. Charter buses operate in all the three localities but it catered significant travel demand in Janakpuri. Cycle-rickshaws are banned from operating in certain areas of New Delhi. Of the three areas studies, cycle-rickshaws are operated on few routes of Janakpuri and Paharganj.

5.2.2 Vehicle ownership pattern

Table 5.4 shows the personal vehicle ownership pattern in each of the areas by vehicle type across income groups. Two-wheeler is a predominant mode of transport

ın Delhi as nearly 45% of households owned this type of vehicle, followed by cars and bıcycles with 15% and 13% respectively. Around 49% of households did not have any vehicle of their own and they either had to depend on walking or on publıc transport.

Table 5.4. Percent of households with different vehicles

Income group	**Two-wheelers**	**Cars**	**Cycles**
Paharganj			
I	11.11	0.00	22.22
II	34.35	0.43	9.13
III	66.67	5.26	14.04
IV	61.90	28.57	2.38
All	41 30	8.10	10 12
R K Puram			
I	17 65	0 00	35.29
II	34 88	2.33	32 56
III	54.17	12.50	20 83
IV	56.79	41.98	3.70
All	46 67	23.03	16 97
Janakpuri			
I	10 00	0 00	60.00
II	46.30	3.70	11.11
III	60.87	19.57	6.52
IV	75.00	38.75	1.25
All	51.30	23.48	17.39
All localıtıes			
I	11.49	0 00	36.49
II	38.89	1 31	13.40
III	53 38	10 14	10.81
IV	64.11	35.19	2.44
All	44.88	14.85	13 27

Note: Due to multiple vehicle ownership, the percentage of households with and without a vehicle may not add up to 100

Cycle was a predominant mode among the lowest income households and ıts ownershıp declines with increase in income, whereas in the highest income households, the ownership of two-wheelers and cars were quite significant (64% and 35% respectively). Vehicle ownershıp of two-wheelers and cars had shown an increasıng trend with income.

The type of vehicle owned varies substantıally between location and income levels. Survey results indicated relatively low vehicle ownership in Paharganj (closest to CBD). This may be because of predominance of walking and public transport as a mode of transport. Vehicle ownership was highest in R K Puram as it ıs an affluent settlement as compared to other localitıes. Major share of personal vehicle owned in low income households of Janakpuri was cycles. Whereas, in R K

Puram motorcycle/scooters was an important mode along with cycles. In the middle income category, motorized two-wheelers were pre-dominant in all the three localities. Whereas, in the highest income category, the share of car was very significant in R K Puram and Janakpuri.

Bicycles constituted more than 70% of total vehicles owned by the lowest income group whereas two-wheelers were predominant in the two middle income groups with 69% and 70%, followed by car and bicycle. In the highest income category, two-wheeler share had gone down marginally to about 63% which was compensated by increase in share of cars.

The general conclusions that can be drawn from the survey data are:

1) declining trend in cycle ownership with increase in income,
2) increasing ownership of two-wheelers and cars with rise in income,
3) predominance of walking and public transport trips in the localities near to CBD, and
4) predominance of car usage (in highest income category) in localities distant from the city centre vis-a-vis localities near to CBD.

5.3 Modal shift

The rapid increase in two wheeler and car population in the recent years can be attributed to the shift of computers from public mode to private mode or vice versa

5.3.1 Private mode to public mode

Figure 5.2 shows the percentage of households which shifted from private to public mode of transport in the five year period - 1985 to 1989 across different income groups. Figure 5.3 presents various reasons for the shift.

The major shift took place in middle and upper middle income categories The overall shift in all the three localities together was over 1.47% Maximum shift was in R K Puram with over 1.87% followed by Janakpuri and Paharganj with 1 4% and 1.3% respectively. The predominant shift was in R K Puram and could be attributed due to the availability of better bus facility in that area.

Reasons

As shown in Fig. 5 3 the following seven major reasons were given for modal shift from private to public mode of transport.

Code

1. DTC specials are available (26%)
2. To travel longer distances (18%)
3. DTC bus service exists between house to working place (14%)
4. DTC bus service has improved (14%)
5. Ladies DTC specials are available (13%)
6. Fuel price went up (7%)
7. Decline in personal real income (6%)
8. Others (4%)

In some responses, there was more than one reason, but the overlap of reasons is ignored in the analysis.

Fig.5.2. Modal shift of households from private to public modes

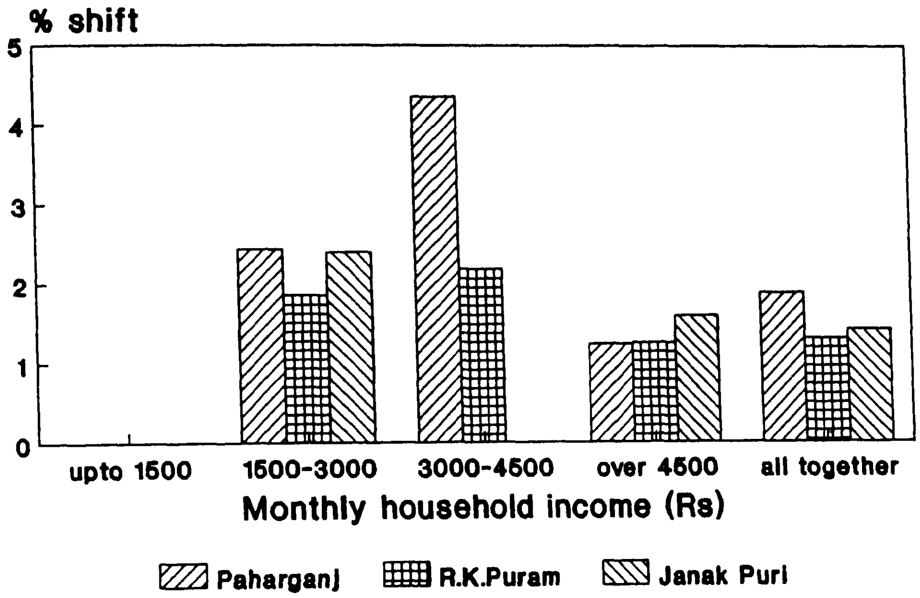
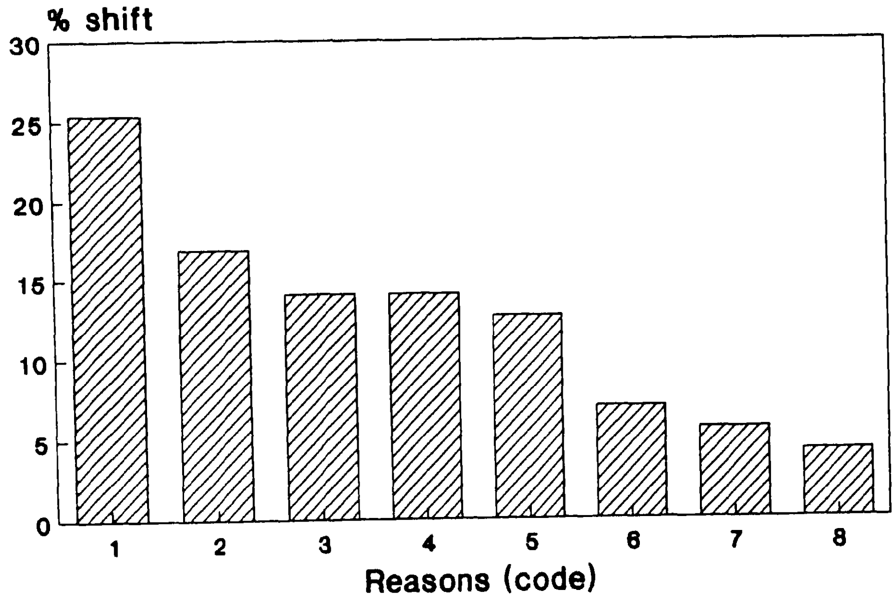


Fig.5.3. Reasons for shift from private to public modes



It is found that 26% of the total shifts reported have given the availability of DTC special bus service and charter service as the reason for the shift. These buses are convenient in terms of comfort and better speeds with fewer stops. Though the fare in chartered bus is higher than ordinary DTC bus, it is observed that some section of people were ready to pay the difference for better comfort. This indicates that by providing better public transport service it is possible to shift passengers from private to public mode and stop further growth in private mode computers. Thus, a greater emphasis is needed in this aspect, not only for better transport service but also for improving efficiency.

The next important reason which 18% of passengers reported was the longer distance they had to commute. 14% of respondents have shifted either because of improvement in accessibility of public transport services from their place of work to residence or due to improvement in the bus service 13% of the respondents (ladies) attributed a shift to the availability of DTC ladies special. These shifts indicate that provision of better public transport services can hinder rapid growth of private vehicles to a considerable extent. 7% of passengers shifted because of increase in fuel prices and 6% of the shifts from private to public mode were due to fall in personal income. In a situation where the growth of fuel cost is causing concern, regulation of sales by adjusting the prices appears to be an alternative proposition, as a measure of oil conservation along with technological and other improvements

5.3 2 Public mode to private mode

This shift is predominant in highest income categories with more than 21% shift compared to 1.36% in lowest income group (Fig. 5.4). The overall shift was more than 12 6% of the three localities surveyed, major shift took place in R K Puram with over 28%, followed by Janakpuri (13 5%) and Paharganj (7.28%). The reason could be that R K Puram is relatively an affluent colony where majority of residents are government employees. The relatively low shift in Paharganj could be because of high traffic density and congestion, where private vehicles cannot manoeuvre smoothly. Also because of proximity to CBD, commuters prefer walking which makes it predominant mode in Paharganj

Reasons

The shift to private mode of transport was due to the following reasons (Fig. 5.5)

Codes

1 Convenience in use (48%)
2 Increase in personal income (20%)
3 Takes less time (18%)
4 DTC buses are overcrowded (5%)
5 Loan facilities are available (2%)
6 DTC bus services are not available (2%)
7 Distance of the working place from household increased (2%)
8 Bus stop is far off from the household (2%)

About 48% of the shifts that were reported are attributed to convenience of personalized vehicle Increase in personal income or reduction in travel time are the reasons for shift amongst 20% and 18% of residents respectively Private vehicle has

Fig.5.4. Modal shift of households from public to private modes

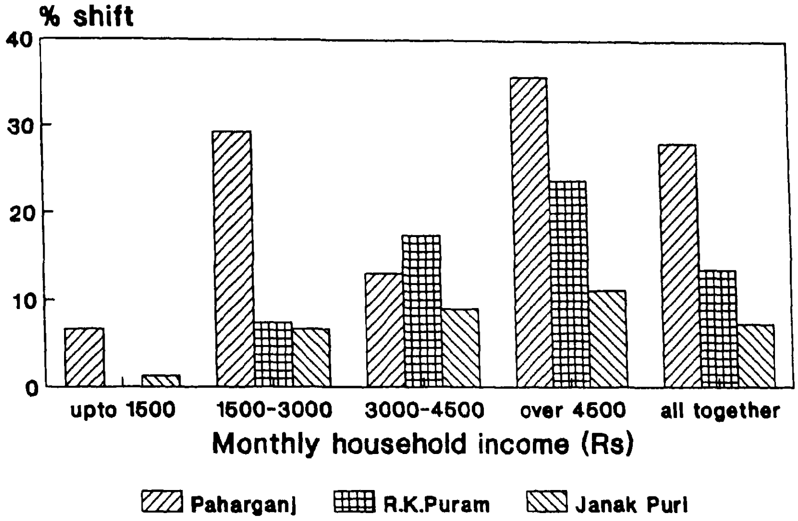
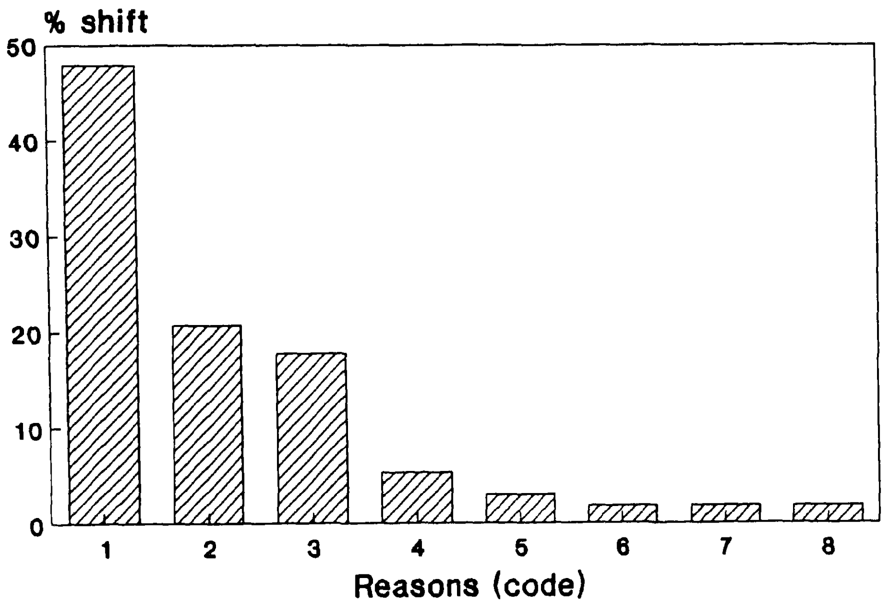


Fig.5.5. Reasons for shift from public to private modes



the advantage of taking the passenger from his doorstep to his place of work and it can be used for other short trips as well as shopping recreation.

A direct correlation is observed between private vehicle ownership and income That is, with the rise in income level more and more people are shifting towards private modes. Also, time and comfort of travel are important factors which has a direct impact on the shift. This coupled with over-crowded bus service is causing the shift of passengers towards private mode of travel.

5.4 Travel demand

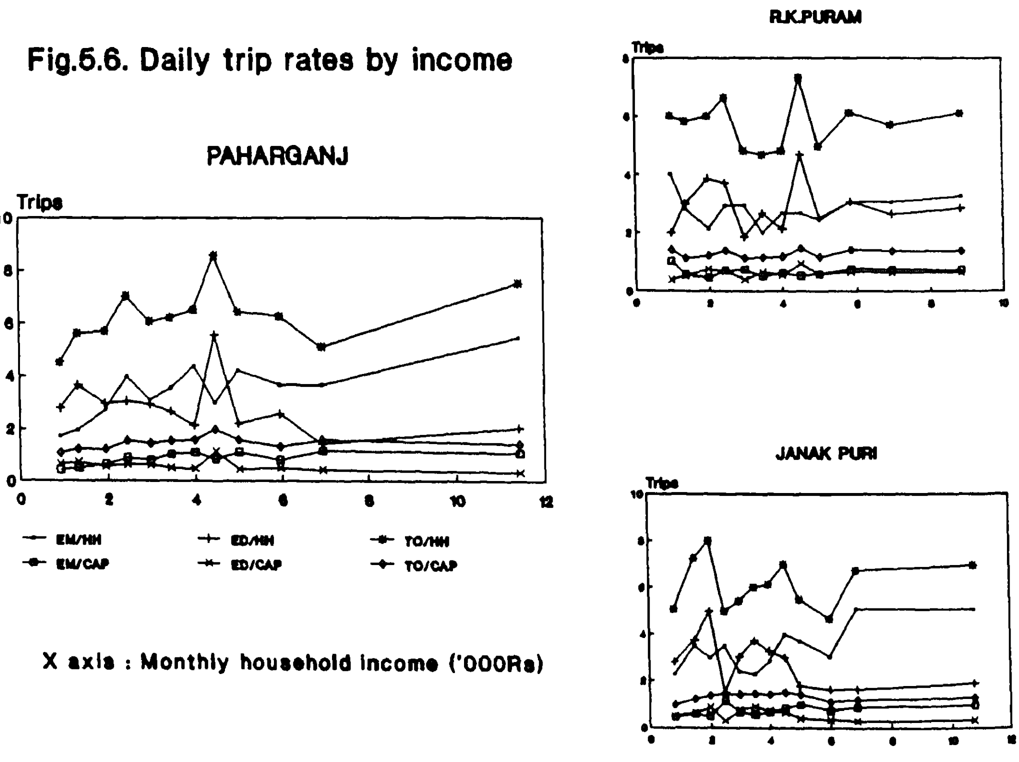
Travel demand can be assessed on the basis of various modes available, average trip rate, trip length, time spent by commuters in travel etc. These parameters are addressed below in detail.

5 4.1 Trip rate

As most of the trips made in urban areas are for places of work and educational institutions, data was obtained for trips related to education and work where social and leisure trips are ignored. Previous studies have shown that social and leisure trips have marginal effect on the overall trip rates (Maunder 1984)[3]. Therefore, the present study has not considered social and leisure related trips.

Figure 5.6 shows per-capita and per household trip rates across localities with respect to income. In general, trip rate shows a marginal upward trend with increase in income for all the three localities. This income effect on trip seems to be associated largely with increased educational activity in more affluent localities Location effect on per capita daily trip rate is very prominent with 1 65, 1.27 and 1 26 trips respectively for Paharganj, R K Puram and Janakpuri respectively Residents of colonies at the periphery of the city were making fewer trips than those (of similar income) living close to the city centre. This indicates that households located more than 20 km from the city centre were likely to have per capita trip rates 31% lower than those close to the city centre. The households living near the CBD have relatively lower suppressed demand and can make all the trips they desire because of the wide modal options (including walk) available to them This was not the case in more distant colonies where only essential trips were made.

Fig.5.6. Daily trip rates by income

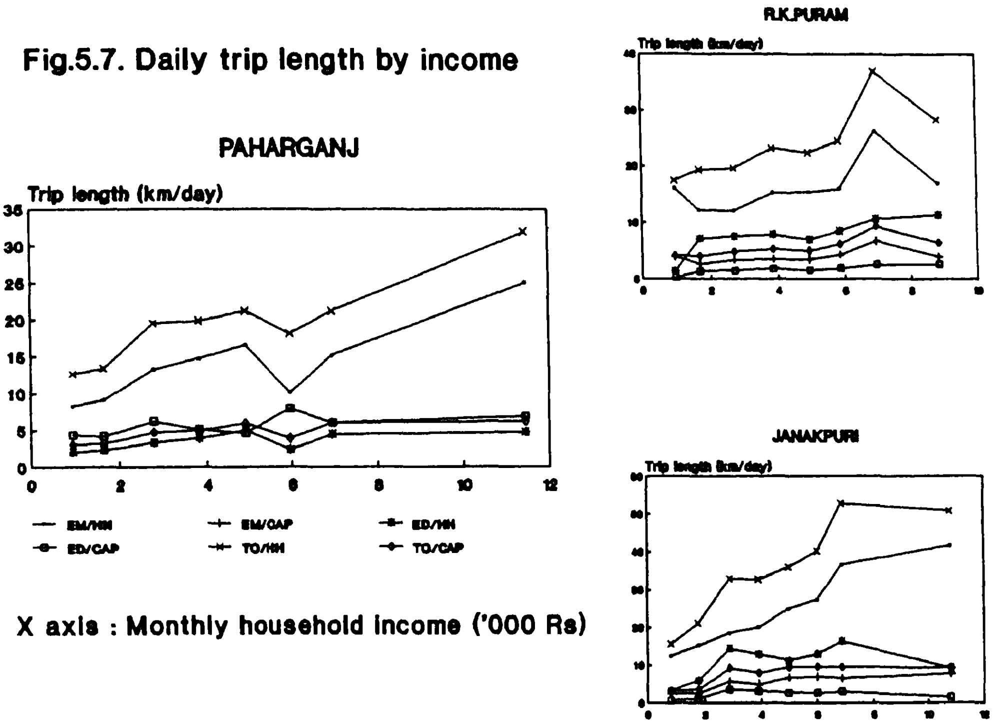


X axis : Monthly household income ('000Rs)

5 4.2 Trip length

Figure 5 7 shows trip length across income groups for three localities surveyed. Trip length increased as one moves away from CBD. Average daily trip length per household was 19, 24 and 32 km for Paharganj, R K Puram and Janakpuri respectively. The trip lengths for employment were longer than educational trips. The average constancy of travel time and an upward trend in trip kms with rise in income suggests that higher income commuters had higher journey speed. For any daily trip kilometerage, the total travel times were as much as 19% higher for lower income groups. This undoubtedly reflects differences in the modal choice and ease of access to transport facilities (both personal and public), which the two income groups have.

Fig.5.7. Daily trip length by income



In Paharganj, trip length have shown an increasing trend with respect to income whereas the travel time was consistent across income groups. This can be explained by the modal choice (walking) available among the lower income categories.

In R K Puram, trip length had increased marginally whereas travel time declined This clearly illustrates that more people in the higher income households preferred to travel in their own vehicles which took relatively less time as compared to other public modes of transport.

Janakpuri, which has longer trip lengths vis-a-vis other localities, have shown an increasing trend with increase in income The trip length for employment have shown a steady rise across income groups.

Income elasticity of trip kilometerage

To capture the influence of income on trip length, a regression analysis is performed A good linear fit is obtained between trip length and income which is given by the equation,

$$Y = 12.13 + 0.11232X \qquad R^2 = 0.89$$

where,
Y = trip length (km/day)
X = monthly household income (Rs.)

The equation suggests that with a rise in income, trip length is likely to go up as more and more people will prefer to shift towards suburban areas. Trip length elasticity for Delhi is estimated to be 0.51. This shows that a 100% increase in income would lead to 51% increase in trip length for Delhi as a whole This gives a strong indication of future likely growth of travel demand and energy consumption

5.5 Energy implications

The two major fuels used for the propulsion of vehicles are Motor Spirit (MS) commonly known as petrol, and High Speed Diesel (HSD) oil. MS is exclusively used in road transport vehicles, whereas HSD is also used in industry and agriculture sector other than transport. Two-wheelers, three-wheelers (auto-rickshaws), taxis and some jeeps/vans/cars are run on MS It is found from the production figures (ACMA 1985)[4] that 75% of cars/jeeps/van are run on MS and the remaining 25% on HSD.

5.5 1 Fuel sales in Delhi

Table 5 5 give the petrol and HSD sales in Delhi during the period 1973-74 to 1992-93 The petrol consumption during the same period has gone up from 119 thousand tonnes to 363 thousand tonnes. The gross fuel consumption is growing steadily, though there are fluctuations in the growth rate over the years Petrol consumption has grown from 1980-81 to 1992-93 at the rate of 9.8% annually Similarly, the diesel consumption grew rapidly till 1987/88, but there was a sharp fall of over - 10% in the year 1988-89 This can be attributed to Delhi Electricity Supply Undertaking's (DESU) switching over to naphtha and natural gas from HSD for power generation during 1988-89 which otherwise would have consumed 100 thousand tonnes of HSD in their gas turbine plant Consumption of HSD was around 810 thousand tonnes during 1992-93. Between the period 1980-81 and 1992-93, diesel consumption in Delhi grew at the rate of 14 6% annually

Table 5.5. Consumption of Petrol and Diesel in Delhi

Year	**Petrol** 10^3**t**	**High speed diesel** 10^3**t**
1973-74	118 60	157.81
1974-75	100 50	187 20
1975-76	99 70	205 40
1976-77	105 30	218.20
1977-78	114 65	263.60
1978-79	124 00	309 00
1980-81	133 00	377 00

Table 5.5 (contd.). Consumption of Petrol and Diesel in Delhi

Year	**Petrol** 10^3t	**High speed diesel** 10^3t
1983-84	171 00	449.00
1984-85	187.00	474.00
1985-86	205.00	530.00
1986-87	233 00	621 00
1987-88	260 00	741 00
1988-89	293.00	665 00
1989-90	330.00	718.00
1990-91	344 00	732 00
1991-92	355.00	747 00
1992-93	363.00	810 00
2000-01 (estimated)	670 28	1851 22
Annual growth (%) 1973-74 to 1980-81	1 65	13 25
Annual growth (%) 1980-81 to 1992-93	9 77	14 60

Using consumption data of petrol and diesel oil from Table 5.5, the following time trend equations are established to project the corresponding supply figures for 2001.

(a) Petrol

$$Log\ Y_t = 4.39 + \underset{(18.66)}{0.076\ t} \qquad R^2 = 0.95$$

(b) HSD

$$Log\ Y_t = 5.14 + \underset{(21.33)}{0.09\ t} \qquad R^2 = 0.96$$

where,

Y = Fuel consumed
t = (year + 1) - 1973-74

These two equations have been used to extrapolate the supply potential of petrol and diesel oil in Delhi during 2001, which is estimated to be 670 thousand tonnes and 1851 thousand tonnes respectively, if the present growth of fuel consumption continues.

5.5 2 Energy demand for passenger transportation

Under section 3.16, energy demand for passenger movement has been estimated in Table 5 6. Petrol consumption for transportation during the same period was 364 thousand tonnes whereas demand for HSD was 476 thousand tonnes. The corresponding sales during the same year are 355 and 747 thousand tonnes. These figures are comparable with the consumption values. The share of HSD utilized for passenger transportation is 64% of the total sales. The remaining share is going for freight movement and also in industries and commercial establishments. The passenger transport sector is the sole consumer of petrol. Cars and two-wheelers are the major consumers of petrol with 184 and 99 thousand tonnes, whereas HSD consumption in buses is estimated to be 394 thousand tonnes in 1991.

Table 5 7 presents the projected energy demand for passenger transportation in Delhi during 2001. Petrol and diesel demand in 2001 will increase by about 3 times when compared with 1991 energy demand estimates

Table 5 6 Energy demand for passenger transportation in Delhi during 1991

Vehicle type	Energy source	Number of motor vehicles in 1991	Average norms per vehicle[1]				Total travel demand	Energy demand in 1991	
			Occupancy	Vehicle utilization	Energy consumption	Operating energy intensity			
			(-)	(km/yr)	(km/lit)	(pkm/lit)	(10^9pkm)	(10^6lit)	(10^3t)
Cars/Jeeps	Petrol	320807	2 6	9855 00	12	31 20	8 22	263 46	184 42
Cars/Jeeps	Diesel	106936	2 6	9855 00	12	31 20	2 74	87 82	74 65
Motor cycles/Scooters	Petrol	1294066	1 5	4927 50	45	67 50	9 56	141 70	99 19
Auto rickshaws	Petrol	65829	1 76	33488 75	25	44 00	3 88	88 18	61 73
Taxis	Petrol	7820	1 57	31025 00	9	14 13	0 38	26 96	18 87
Taxis	Diesel	2607	1 57	31025 00	9	14 13	0 13	8 99	7 64
Buses	Diesel	19671	44 72	82500 00	3 5	156 52	72 57	463 67	394 12
							Total Petrol	520 30	364 21
							Total Diesel	560 48	476 41

Table 5 7 Energy demand for passenger transportation in Delhi during 2001

Vehicle type	Energy source	Number of motor vehicles in 2001	Average norms per vehicle as assumed in Table 5 5				Total travel demand	Energy demand in 2001	
			Occupancy	Vehicle utilization	Energy consumption	Operating energy intensity			
			(-)	(km/yr)	(km/lit)	(pkm/lit)	(10^9pkm)	(10^6lit)	(10^3t)
Cars/Jeeps	Petrol	744117	2 6	9855 00	12	31 20	19 07	611 11	427 77
Cars/Jeeps	Diesel	248039	2 6	9855 00	12	31 20	6 36	203 70	173 15
Motor cycles/Scooters	Petrol	4861152	1 5	4927 50	45	67 50	35 93	532 30	372 61
Auto rickshaws	Petrol	167022	1 76	33488 75	25	44 00	9 84	223 73	156 61
Taxis	Petrol	12657	1 57	31025 00	9	14 13	0 62	43 63	30 54
Taxis	Diesel	4219	1 57	31025 00	9	14 13	0 21	14 54	12 36
Buses	Diesel	53142	44 72	82500 00	3 5	156 52	196 06	1252 64	1064 74
							Total Petrol	1410 77	987 54
							Total Diesel	1470 89	1250 25

References

Chapter 5

1 Maunder, D A.C. 1982. "Household and travel characteristics in two middle income residential colonies of Delhi, India, 1981", Transport and Research Laboratory, Supplementary report 755, Department of Environment and Department of Transport, Crowthrone, Berkshire.

2 Maunder, D A C. 1983. "Household and travel characteristics in two suburban residential areas of Delhi, India, 1982", Transport and Road Laboratory, Supplementary report 767, Department of Environment and Department of Transport, Crowthrone, Berkshire

3 Maunder, D A C 1984. "Trip rates and travel pattern in Delhi, India", Transport and Road Research Laboratory, Research Report 1, Department of Transport, Berkshire.

4. Automotive Components Manufacturers Association (ACMA) 1985, "Automotive Industry of India - Facts and Figures - 1985", Bombay.

5. ENCON. 1987 Estimation of Total Road Transport Freight and Passenger Movement in India for the year 2000 AD Final report submitted to the Department of Surface Transport (Roads Wing), Government of India Prepared by the Engineering Consultants Private Limited, New Delhi.

Chapter 6

Energy Demand in the commerical sector

The rapid pace of urban development leading to growth of commercial establishments has pushed the electricity demand levels upwards. In order to examine the resultant trends, the study involves a survey of about 450 shops in the city of Delhi. Based on the data collected, we attempt to analyse the electricity consumption patterns for various end uses with respect to different plinth area of various categories of shops.

6.1 Electricity consumption for lighting in shops

Table 6.1 presents the electricity consumption pattern per unit of plinth area for lighting in different categories of shops viz. textiles, autoparts, food articles, building materials, consumer goods and restaurants.

Table 6.1. Electricity consumption for lighting per unit of plinth area in different category of shops

Category of shops	No. of obs.	Wh/sqm			
		Average	Standard Deviation	Min	Max
Textiles	154	527.06	409 59	38 10	2129 63
Auto parts	12	105.42	71.63	15 24	250 60
Food articles	27	379 20	416 57	33 33	1716.67
Building materials	14	173 09	81 53	38.10	277.78
Consumer goods	212	320 89	313 70	9 52	1991.11
Cosmetics & toiletories	13	446.15	430.22	27 55	1173.33
Consumer goods including medicines, plastics and chemicals	51	234 82	155 02	24.44	711 11
Footwear, optical and watch	52	416 68	355 05	40 74	1777 78
Stationary, xerox & photo studio	18	204 47	151 41	40.74	740.74
Jewellery	28	505 77	455 17	115.87	1991.11
Electrical appliances, radio & television	26	195 52	130 11	9.52	622.22
Furniture & Fixtures	13	126 59	123 95	16.36	460.44
Crockery and utensils	11	365 01	241 43	52.15	800
Restaurants	21	203.47	145 68	20 32	562.50

The data reveals that the electricity consumption for lighting per unit of plinth area varies significantly across different categories of shops. Average consumption figures across all shop types vary between 105 and 528 Wh/sqm.

Figures 6.1 through 6.6 present the percentage distribution of shops (viz. textiles. autoparts, food articles, building materials, consumer goods and restaurants respectively) falling in various electricity consumption blocks per unit of plinth area.

Fig. 6.1. Electricity demand for lighting - Textiles

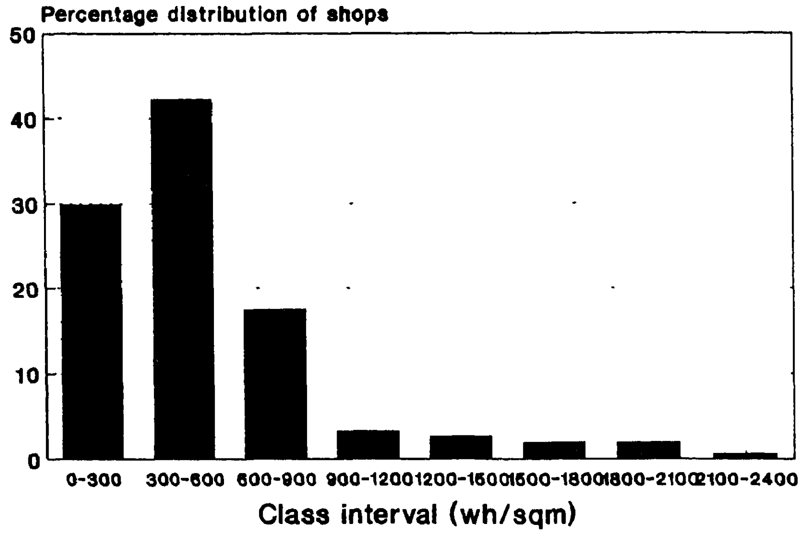


Fig. 6.2. Electricity demand for lighting - Auto parts

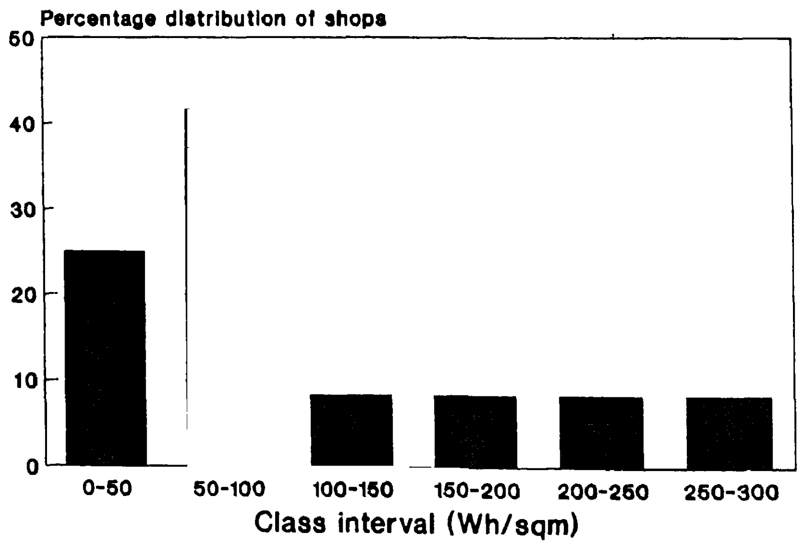


Fig. 6.3. Electricity demand for lighting - Food articles

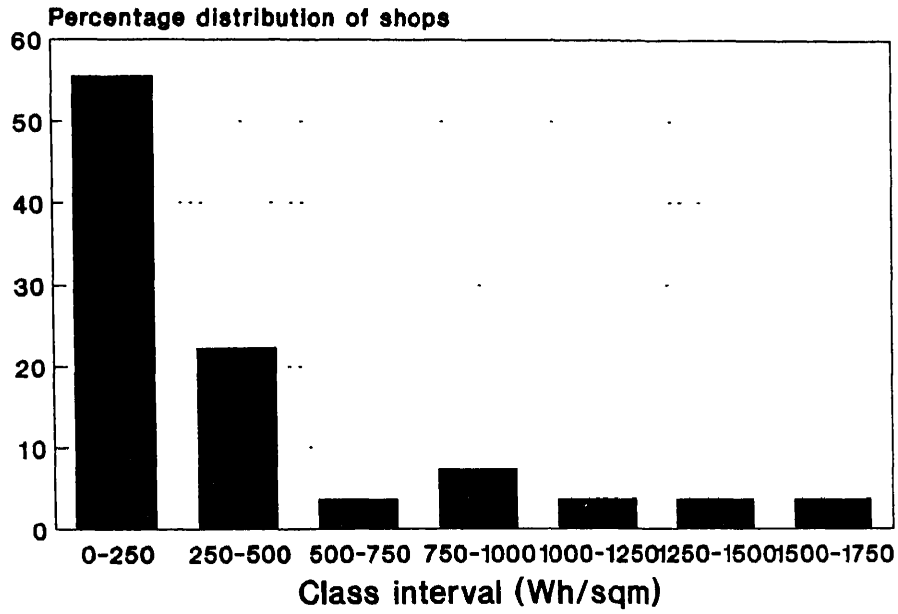


Fig. 6.4. Electricity demand for lighting - Building materials

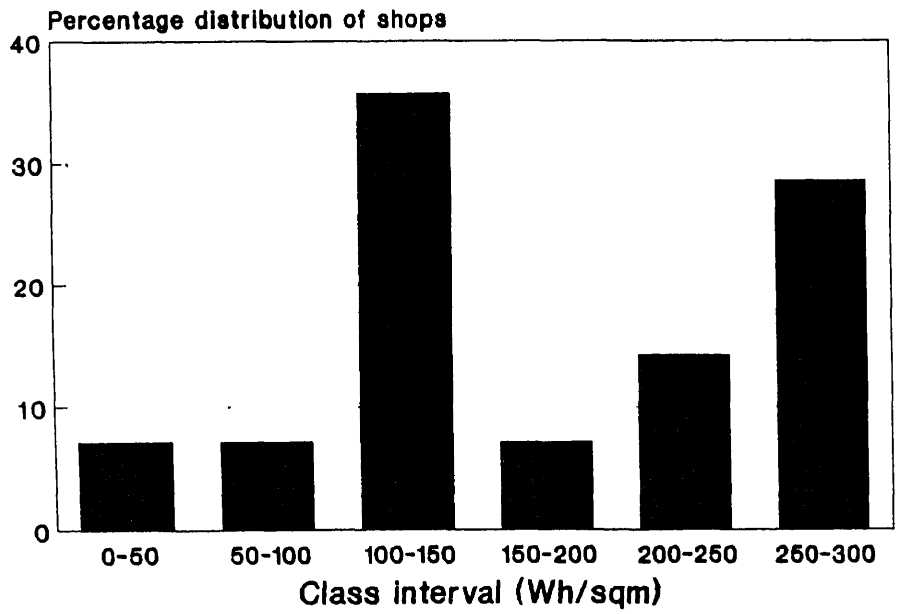


Fig. 6.6. Electricity demand for lighting - Restaurants

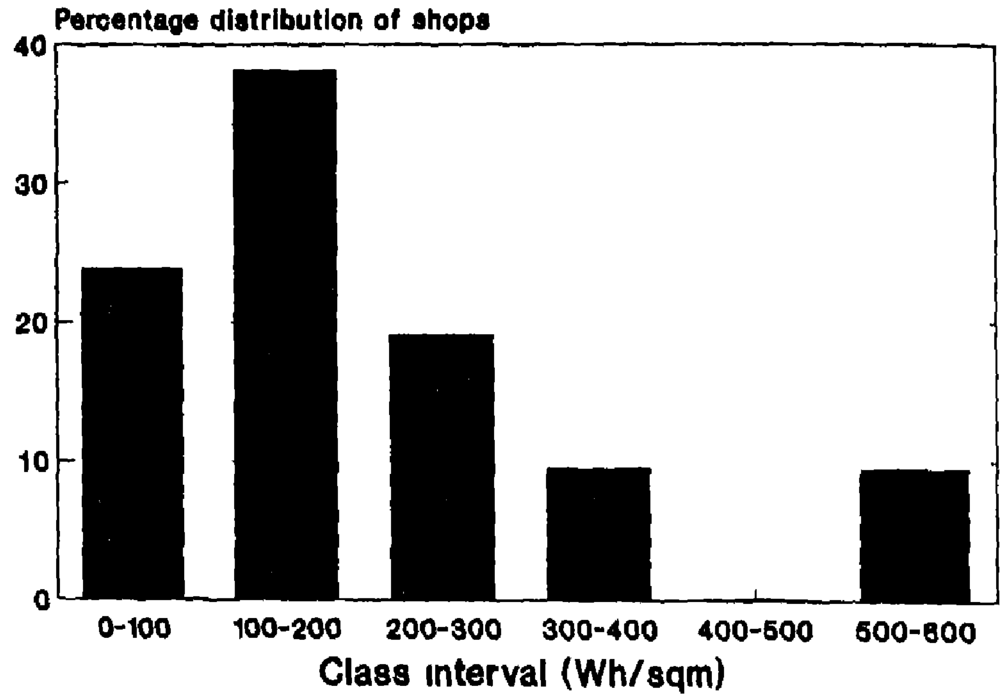
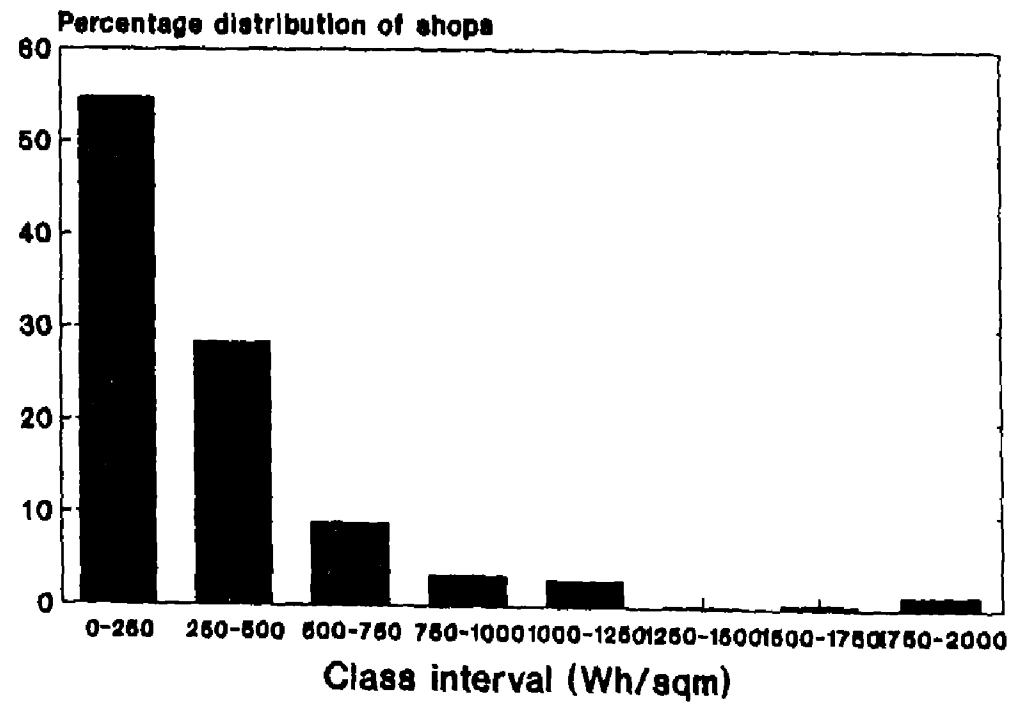


Fig. 6.5. Electricity demand for lighting - Consumer goods



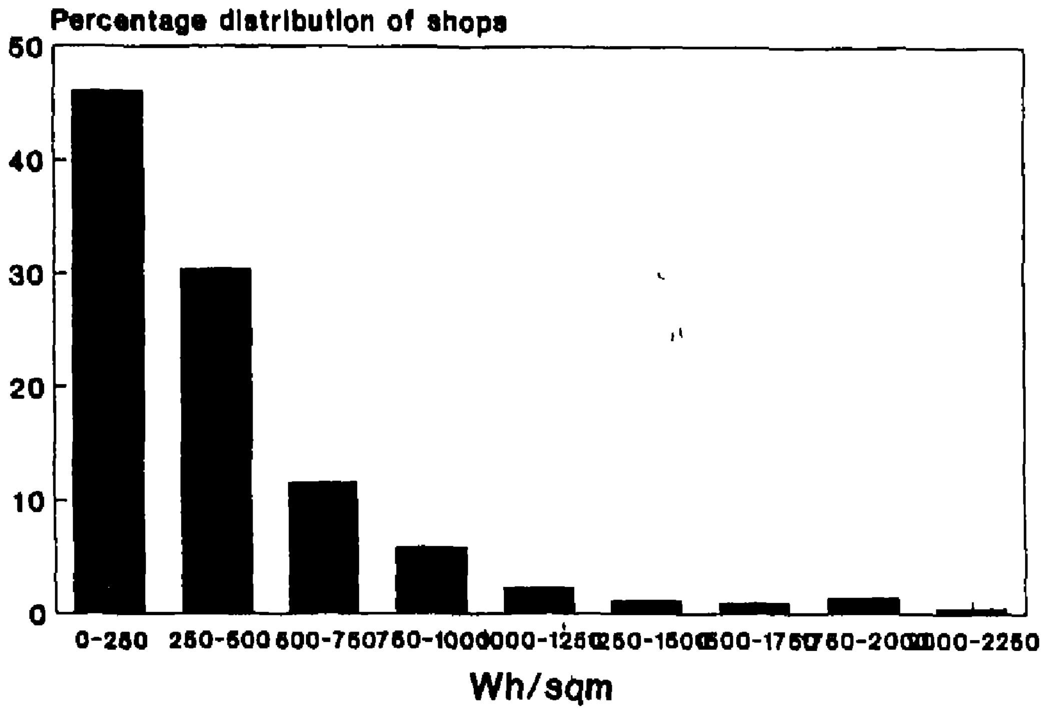
The average electricity consumption is found to be the highest in textile shops (527 06 Wh/sqm) Even though most of the units consume between 300-600 Wh/sqm, there exist some units which have much higher intensity levels of electricity consumption Consumption figures for shops dealing in hardware and building materials average 173 09 Wh/sqm, while restaurants are found to consume an average of 203 47 Wh/sqm Further, the data shows that the lowest average electricity consumption is in shops dealing in auto parts (105 42 Wh/sqm) with more than fifty per cent of such units using less than 100 Wh/sqm for lighting Average electricity usage in shops dealing with food articles & consumer goods falls in the same range

averaging about 350 Wh/sqm Also, the distribution for these two categories indicates similar patterns with more than 75% of the units consuming upto 500 Wh/sqm of electricity for lighting purposes while very few units use higher levels of lighting intensity

Within the consumer goods category, lighting consumption per unit of plinth area is seen to be significantly higher in shops where the consumers indulge in examination of the product before making a choice in purchasing (eg jewellery, footwear, optical goods and cosmetics)

The distribution of all shops covered in the survey with respect to different electricity consumption blocks per unit of plinth area is presented in figure 6 7

Fig. 6.7. Electricity demand for lighting - All shops together



The figure reveals that more than half of the shops in Delhi consume electricity in the range of 0-500 Wh/sqm for lighting with decreasing number of shops consuming higher levels of electricity intensity

Presently the data is being analysed to understand the distribution trends in electricity usage for other enduses viz space cooling To understand the seasonal variation, data for winter and summer months is being looked at separately to identify qualitative and quantitative trends in electricity usage for various category of shops For restaurants, data is being analysed to understand the electricity consumption pattern for cooking purposes

Annexure 3.1

Relationship between household income and electricity use

The assumption that household with higher income level will have higher electricity consumption is tested by analyzing the household survey data A very good linear fit was observed between household income and the electricity consumption (Figure 1)
Let Y = Average household monthly electricity bill in Rs.
and X = Average household monthly income in Rs
then,

$$Y = 14\ 71074 + \underset{(21\ \ 70)}{0\ 015911}\ X \qquad R^2 = 0\ 091$$

It may be mentioned here that in Delhi there were three different electricity tariff rates for different consumption blocks in the domestic sector during 1989 - the year of the household survey (Table a)

Fig 1 Income and electricity use

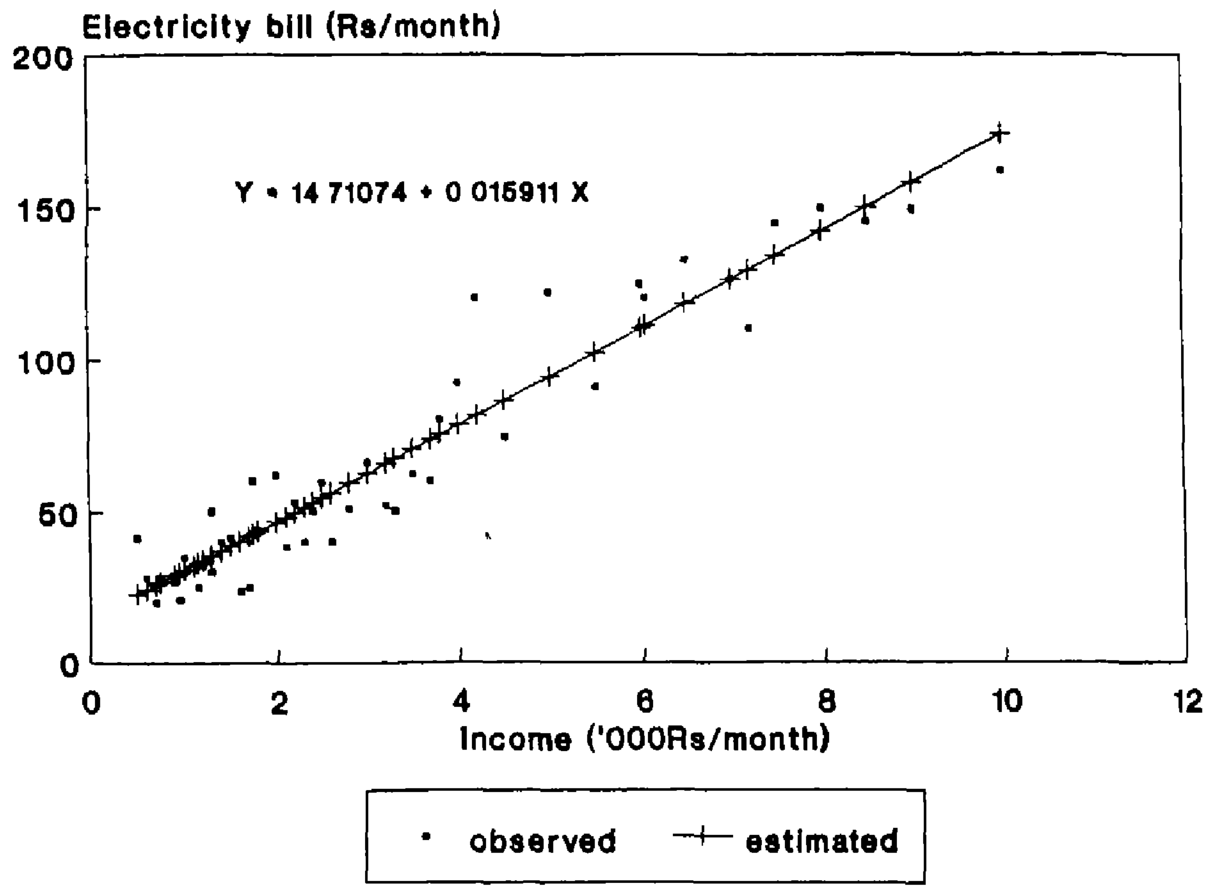


Table a Tariff structure in the domestic sector

Consumption block (kWh)	Electricity rate (Rs./kWh)
0-100	0 25
100-200	0 32
over 200	0 75

Using the above linear equation, Table b presents the estimated monthly electricity consumption in different household income categories during 1989. Table b shows how with rise in income the electricity consumption increases.

Table b. Income vs electricity consumption

Monthly household income (Rs.)	**Monthly household electricity bill (Rs.)**	**Monthly household electricity consumption (kWh)**
1000	30 62	111.32
1500	38 58	136.18
2000	46.53	161.04
2500	54.49	185.90
3000	62.44	214 21
3500	70 40	247 02
4000	78.35	279.84
4500	86 31	312.65
5000	94 27	345 47
5500	102.22	378 29
6000	110.18	411.10
6500	118 13	443 92
7000	126.09	476 74
7500	134 04	509.55
8000	142 00	542 37
8500	149.95	575 19
9000	157 91	608.00
9500	165 87	640.82
10000	173 82	673.64

Annexure 3.2

Household schedule

Prepared by the
Tata Energy Research Institute, New Delhi
for the CEC Phase II study on Energy & Urbanization

May 1989

Schedule No. | | | | |

A. General Information

1 House address:. . ...   2. Name of the Respondent: ... .

3 Total covered floor area (sq.m) .. .. 4. No. of rooms. ....

5. Family size ... . 5 1 Adult: (>18 yrs.) . .. 5.2 Young: ... .

6 No of persons under different categories

Category	Employed	Un-employed	Students	Household activities	Business
Number of adults					
Number of young					

7 Actual monthly household income (Rs).

7 1 Present . ...

7 2 Five years back. . . .

8 Investigator's name ...

9 Interview date: . .

B. Domestic activities

1 Monthly energy consumption pattern:

Fuel type	Monthly consumption			Unit cost (Rs)	Source of supply (code)	Time spent (hours)		
	Unit	Summer	Winter			Cooking	W heat	Light
1 1 LPG	cylinders							x
1 2 Kerosene	lit							
1 3 Soft coke	kg							x
1 4 Firewood	kg							x
1 5 Dungcake	Kg							x

1 6 How long do you have to get LPG supply (days)?

2 Present fuel usage pattern according to end-uses with respect to consumption five years back.
Pl. fill up this box with '1' if you are using/or used this fuel and 'o' if you are presently not using or didn't use.

End use	Present usage						Five years back						Reasons for shifting (code)
	LPG	Ker	Coke	F wood	Dung-cake	Elec	LPG	Ker	Coke	F wood	Dung-cake	Elec	
2 1 Cooking													
2 2 Lighting													
2 3 W heat													
2 4 Sp heat													
2 5 Sp cool													

3 Electric Appliances in Use

Appliance (code)	Nos	Total watts	Avg hours used daily		since when it is used (years)
			Week days	Holidays	

Appliance (code)	Nos	Total watts	Avg hours used daily		since when it is used (years)
			Week days	Holidays	

4 Total electricity bill (Rs /month) Summer month ☐ Winter month ☐

C. Travel Characteristics

1. Personalized vehicle ownership pattern

Vehicle code	Year of purchase	Total average kilometre run weekly (km)	Monthly expenditure (Rs.)	
			Fuel	Services & Repair

2 Purpose-wise usage of different modes of transport

Travel characteristics	Persons no	Mode of travel	Daily trip (Nos /day)	Daily trip length (km/day)	Days travel in a week	Average occupancy (person)	Time taken daily (min/day)
Work place	1						
	2						
	3						
Work related	1						
	2						
	3						
Education	1						
	2						
	3						

2 1 How many persons in the household have shifted over in the last five years from,

2 1 1 private vehicles to public mode of transport (person) ....
and reasons for shifting (specify code) ....

2 1.2 public mode of transport to private vehicles (person) ....
and reasons for shifting (specify code) ....

for codes, see overleaf

CODING SHEET

Source of supply - Section B1

1 - Ration shop
2 - Open market
3 - Collected
4 - Purchased
5 - Prepared

Reasons for shifting - Section B2

1 - Fuel price came down
2 - Fuel price went up
3 - Income of household went up
4 - Income of household went down
5 - Family size increased
6 - Family size decreased
7 - Convenience in terms of usage, handling and storage
8 - Difficulty in obtaining
9 - Reliability of supply has gone down
10 - Distance of the household from source of supply increased
11 - Efficiency of fuel use increased

Electrical appliances - Section B3

Cooking and baking

1 Cooking/oven/toaster/coil heater

Lighting

2. Incandescent bulb

3. Fluorescent bulb

Water heating

4. Immersion rod

5. Geyser/boiler

Space cooling

6 Ceiling fan

7 Table/pedestal fan

8. Desert cooler

9. Air conditioner

Space heating

10. Room heater

11. Blower

Others

12. Electric iron

13. Washing machine

14. Exhaust fan

15 Refrigerator

16. Television (black & white)

17. Television (colour)

18. Water pump

19. Mixie/grinder

Vehicle mode - Section C1
Private vehicles

Private vehicles

1 - 2 wheeler < 100 cc
2 - 2 wheeler 101-175 cc
3 - 2 wheeler 175-350 cc
4 - Car · Maruti
5 - Car : Fiat
6 - Car : Ambassador
7 - Car . Others
9 - Taxi
10 - Autorickshow
11 - Car pool : Fiat
12 - Car pool : Ambassador
13 - Car pool : Others
14 - Bicycle
15 - Walking

Public vehicles

16 - Under DTC operation bus
17 - Charter/School bus
18 - Staff car

Reasons for shifting - Section C2.1
Shift from public to private modes
1 - Takes less time
2 - DTC buses are overcrowded
3 - DTC bus service gone down
4 - DTC bus fare went up
5 - No DTC bus service between house to the working place
6 - Charter bus service do not exist now
7 - Bus stop is far off from the household
8 - Charter bus fare went up
9 - Increase in personal income
10 - Loan facilities available
11 - Distance of the working place from households have increased
12 - Convenience in use
13 - Car pooling possible and preferred because of convenience

Shift from private to public modes
1 - DTC specials are available
2 - Ladies DTC specials are available
3 - DTC bus service exists now between house to the working place
4 - Safer in travelling
5 - DTC bus services have improved
6 - Decline in personal real income
7 - Fuel price went off
8 - Economy scale in fuel expenditure because of car pooling
9 - To travel longer distances

Annexure 3.3

QUESTIONNAIRE - I
Distribution of different types of shop in market
(Sept. - Oct. 1993)

TATA ENERGY RESEARCH INSTITUTE
103 JOR BAGH, NEW DELHI 110 003

Category of shops	**Frequency distribution of shops**	**Percentage distribution**
TEXTILE		
AUTO PARTS		
FOOD ARTICLES		
Fruits & vegetables		
Grocery		
Foodgrains		
Oil & ghee		
BUILDING MATERIALS		
Hardware		
Iron & steel		
Timber & Plywood		
CONSUMER GOODS		
Cosmetics & toiletries		
Footwear		
Electrical goods		
Medicines & chemicals		
Rubber & plastics		
Hosiery		
Books & stationary		
Bicycle, tyres & tubes		
Furniture & fixtures		
Crockery & utensils		
Radio & television		
Optical & watch		
Pan & cigarette		
Flour mill		
Barbar shop		
Photo studio/Xeroxing		
Others		
RESTAURANT		
TOTAL SHOPS		

Annexure 3.4

QUESTIONNAIRE - II
Energy consumption pattern in retail shops in Delhi
(Oct. - Nov. 1993)

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I. General Information

1 Market name: ______________________
2. Respondent's name: ______________________
3. Shop name: ______________________
4 Address: ______________________
5 Type of shop: ______________________
6 Plinth area of the shop: ______________________
7 No. of persons employed ______________________
8. Phone No: ______________________

II. Connected load of electricity

1 What is the total connected load of electricity in your shop (KW). __________
2 What is your monthly electricity bill in summer months (Rs./month). __________
3. What is your monthly electricity bill in winter months (Rs./month). __________

III. Inventory of electrical appliances and their usage

S No	Type of appliance	Total Nos.	Total wattage	Average hours used daily
A.	**Lighting**			
1	Bulbs[a]			
2	Tubes[b]			
3	Mercury bulbs			
4.	Sodium bulbs			

No. of bulbs
a 20 Watt __________
b 40 Watt __________
c 60 Watt __________
d 100 Watt __________
e 200 Watt __________
f 500 Watt __________

No. of tubes
a 20 Watt __________
b 40 Watt __________

S No	Type of appliance	Total Nos	Total wattage	Total storage capacity of water	Average hours used daily
B.	**Space cooling**				
1.	Centralised air conditioner				
2.	Decentralised air conditioner				
3	Water air cooler				
4	Dry air cooler			x	
5.	Ceiling fans			x	
6	Pedestal/table fan			x	
7.					
C.	**Space heating**				
1.	Centralised air conditioner			x	
2	Decentralised air conditioner			x	
3	Air blower			x	
4.	Coil heater			x	
5.					
6.					
D.	**Water heating**				
1.	Boiler				
2.	Geyser				
3					
4.					
E.	**Others**				
1.	Refrigerator			x	
2.	Television (colour)		Small/big	x	
3	Television (B/W)		Small/big	x	
4	Exhaust fan			x	
5.	Radio/Tape recorder			x	
6	Water cooler				
7					
8					

S No	Type of appliance	Total wattage	Average hours used daily
F	Cooking		
1.	Cooking range		
2.	Hot plate		
3	Hot case		
4.	Micro oven		
5	Cooking grill		
6	Toaster		
7			

IV. Captive Gensets: Have you got any generator (Diesel/Kerosene/Petrol)?

S No	Parameters	
1	Number of Gensets	
2	Total generating capacity (kW)	
3	Average daily utilisation (hrs)	
a	in Peak season (hrs)	
b	in Slack season (hrs)	
4a	Peak months used (specify the months)	
b	Slack months used (specify the months)	
5	Consumption of fuel per hour (litres)	

V. Energy Consumption Pattern

Fuel Type	Physical unit	Fuel used (Yes/No)	Total Monthly Expenditure (Rs)	Total consumption in physical unit
LPG	Cylinders			
Kerosene	Litres			
Firewood	Kgs			
Coal/Charcoal	Kgs			
Diesel	Litres			
Fuel Oil	Litres			
Others				

VI. Please specify whether you have adopted any conservation measure, if so, what measures and when?

	What measures?	When (specify month/year)
1		
2		
3		
4		

Annexure 4.1

Assumptions on wattages of electrical appliances

The standard norms used for the wattages of different appliances are given below.

1. Ceiling fans:

blade length more than 36"	= 70 watts
equal to or less than 36"	= 60 watts

2. Pedestal fans:

fan size 12" to 18"	= 40 watts
fan size more than 18"	= 60 watts

3 Desert coolers:

fan size less than 20"	= 150 watts
fan size equal to and more than 20"	= 300 watts

4. Air conditioners:

1 0 tonne	= 1000 watts
1.25 tonnes	= 2000 watts

5 Refrigerators:

165 litres	= 100 watts
235 litres	= 100 watts
286 litres	= 150 watts
310 litres	= 180 watts

6 Television:

For TV screens equal to or less than 14"	= 60 watts
For all other sizes	= 80 watts